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THE

SUGAR-PLANTER'S MANUAL.

LONDON:
SPOTTISWOODE and SHAW,
New-street-Square.

THE

SUGAR-PLANTER'S MANUAL:

BEING

A TREATISE

ON THE

ART OF OBTAINING SUGAR FROM THE SUGAR-CANE.

BY

W. J. EVANS, M.D.

LONDON:
LONGMAN, BROWN, GREEN, AND LONGMANS,
PATERNOSTER-ROW.
1847.

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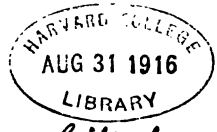

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PREFACE.

To those who are conversant with the present commercial state of the British sugar-producing colonies, it would be useless to point out the great depreciation in value which property therein has within a few years undergone. Many of those persons, unfortunately, are too well acquainted with the fact. Nevertheless it would appear, that generally, even by those whose position would lead us to give them credit for more accurate information, the actual position and capabilities of those countries are subjects but ill understood, though involving questions of the highest interest.

We have the strongest evidences to show, that many plantations which formerly were productive of large revenues to the owners, have not during the last few years paid the expenses necessary to keep them in cultivation; and instead of representing the large capital invested in their formation or purchase, have become altogether worthless and unsaleable.

This unhappy change has elicited various opinions respecting its cause; and these opinions have necessarily influenced the views that have been

taken of the future prospects of those dependencies, and of the measures to be adopted for their relief and improvement.

For instance, we are often told by inconsiderate persons, that the British sugar colonies are worn out, that they have become exhausted; that, as regards the fertility of their soil, &c., they are altogether inferior to the foreign possessions in their neighbourhood, and that no measures that can be taken will enable them to compete with those countries, which are not only more blest in this respect, but which, moreover, enjoy the benefits of cheap labour.

Another party with a sufficient degree of self-complacency, resolves the explanation of "West India distress," by the terms which are so often misused—"absenteeism and extravagance;" upon which they are accustomed to found charges of mismanagement against the entire body of proprietors.

In answer to these assertions, it may be sufficient to say, that so far from the British West India colonies being less fertile than other tropical countries, if we may judge by the products per acre obtained from each, the reverse will be found to be the case; and that, so far from their soil being worn out or exhausted, the heaviest crops have been and are usually obtained in those islands which have been under cultivation for the longest period—that is, in proportion to the agricultural

knowledge displayed, and not to the newness of the soil.

The general charges of absenteeism and extravagance, even if admitted to be general, would fail to explain the *changes* which have taken place: because it is well known that absenteeism prevailed, at least, to an equal extent formerly as it does at the present time; and that the same parties to whom extravagance is imputed, have realised large incomes from estates which now yield nothing.

The West Indian proprietor, on the other hand, regards the measures which have been pursued towards those colonies since 1833, as the causes of his present misfortunes. "Nothing, he contends, has happened that might not have been confidently expected. During the period of slavery the want of labour was unknown, for the great majority of the population was compelled by law to work upon the plantations from day to day. But when that great social change effected by 'The Emancipation Act' took place, vast numbers of the freed people betook themselves to other occupations natural to a free community; many to desultory pursuits, squatting, and vagrancy; while those who continued to work were, from the fewness of their number and the urgent necessity for their services, enabled to dictate their own terms to their employers. The colonies which suffered most from this cause, endeavoured by every means in their

power to counteract its effects by the importation of labourers from abroad. But instead of receiving assistance, their efforts were checked (in a quarter where they least expected) by the restrictive measures of the home government."

This statement is indisputably true. And there can be little doubt that, had the abolition of slave labour been simultaneously coupled with the measures which have since been adopted, and the enormous protection given to British sugars been taken away, the utter and entire ruin of those colonies would have been long since consummated. As it was, many estates were immediately thrown out of cultivation, and the others continued to struggle on solely in consequence of the very high price which their produce yielded in the home market.

These high prices, however, it was evident could not long be sustained, and to relieve the consumer foreign sugars, the growth of free labour, were admitted at greatly reduced duties. I do not think that the West Indian had any reasonable cause of complaint against this measure. It had at least the merit of being consistent with those which had preceded it; and had no restrictions at the same time existed, upon the introduction of labourers into our own possessions, its operation would not have been felt by the planter.

The object of the Sugar Duties' Act of 1846, is the immediate reduction of duties upon all foreign

sugars, and their prospective equalisation in a very short period on all sugars indiscriminately, whether of British or foreign growth, or the produce of free or slave labour. This Act professes to be based upon the principles of free trade, but its details show that it is very far from being so. It removes all protection from sugars, the produce of British possessions; but it has not removed one single restriction imposed upon the grower. These may be stated to be as follow: —

1st. Restrictions imposed upon the obtaining an increase of labour by immigration.

The price of labour forms, indubitably, the most considerable item in the disbursements of a sugar estate in the British West Indies; the planter, therefore, naturally regards it as the chief obstacle to his competition with his foreign rival. In the Spanish West Indian colonies, and in Brazil, not only does slavery exist, but, in spite of all our efforts to check it, the slave trade continues. These of themselves, it might be supposed, would be formidable advantages on the side of the sugar planter in those countries. But they are not the only ones he possesses. If he choose to employ free labour, he can obtain it where he pleases; he can import it under any flag; he is not restricted by any Passenger Act; and he can enter into arrangements, by contract or otherwise, with the parties offering their services, either in the country whence they come, or in that where they are

brought, without limitation of time. From these causes the Spanish planter could import labourers under a British flag, in an English vessel, at an ultimate cost of probably half that which is now paid in our own colonies.

2d. Restrictions on the use of adequate means to obtain both a larger amount of extract, and also one of better quality than is now effected.

Until a very recent period the planter was not permitted, in consequence of the fiscal regulations then in force, to import into this country sugar of a quality superior to that known as Muscovado.

It is to this cause that we must attribute the imperfect mode of manufacture at present practised in the colonies; for how can we expect to find improvement when such effectual means are enforced to prevent it? Although the duties attached to sugars of different qualities have been greatly reduced, they have not been equalised; and a very considerable protection is still kept up in favour of the refiner. This system of taxation is in the highest degree injudicious; for, to quote part of an address from M. Peligot to Admiral Duperré, formerly minister of state for the French colonies, "it has been demonstrated, that the sugar which pre-exists in the cane is white, and it is always so obtained when a part of it has not been destroyed. That the proportion which is obtained is consequently greater the less dark it is in colour." And he asks,

"What ought to be thought of a legislative measure which imposes upon industry the exorbitant obligation of producing at the same time, what is bad in quality and small in quantity, and which places a barrier before one of those things which the laws ought most to respect, progressive amelioration!"

3rd. Restrictions on the importation of the raw material (that is cane-juice in a state of inspissation) for manufacture in this country.

The planter contends, "that he ought to be permitted to bring home his cane-juice in the form of a concrete, on the payment thereon of such a duty as will be commensurate with that at present attached to sugar and molasses; or, that he should be allowed to manufacture it in bond, paying upon his extracts the duties fixed for sugars of corresponding qualities."

If the planter feels that the difficulties attendant upon an improved manufacture in the colonies are for the present, at least, so great as to appear to him to be insuperable, he is right in making the foregoing demand; and which, I should think, there would be little doubt of meeting with cordial reception by the Chancellor of the Exchequer, as it is demonstrative that the sugar duties would thereby be considerably increased in amount; while, from the augmentation in quantity and the improvement in the quality, the public would, *cæteris paribus*, be supplied with a better article at a lower price.

4th. Restrictions on the employment of saccha-

rine substances in the manufactures, &c., of this country.

If the West India proprietor is to be subjected to the disadvantages of free trade, it is manifestly simple justice that his produce should be free too, and should enjoy all the benefits that may be supposed to be obtained by that system of commerce. He has, therefore, a right to demand that sugar, molasses, and treacle, be used for any purpose that the purchaser may choose to apply them, on the payment of a duty equivalent to that now imposed on substances which their employment may be supposed to displace.

5th. Restrictions imposed by the Navigation Laws.

"It is contended that the planter ought to be permitted to ship his produce on board of any vessel which will convey it cheapest, without distinction of flag."

6th. Restrictions on the importation into the colonies of merchandise the produce of foreign countries.

"It is demanded that all discriminating duties cease; that is, that all protective duties in the colonies in favour of British manufactures, &c., be entirely repealed."

7th. Restrictions on the importation of colonial spirits into this country.

"As the colonies form a part of the British empire, the duty on colonial and home-made spirits should be the same."

Such are a few of the restrictions under which the British planter at present labours. I am disposed to agree with him in the belief that if some of the more important of them be not removed, or an equivalent be given to him in the shape of a differential duty, that no means which, unaided, he can pursue will save him from ruin. But, as the removal of the principal among them would be attended not merely with advantage to the colonies, but to the mother country likewise, I apprehend that their continuance will not be for long.

The planter must, however, bear in mind that under all circumstances the struggle will be a great one; and if all those restrictions were entirely, and in the fullest sense of the word, abolished, the difficulties of his position would still be very considerable, and the means of removing them completely would have to be sought for. Strenuous exertions, indefatigable efforts, however necessary, are not the only things that would be required on his part, but if success is to be expected, those efforts would have to be *properly directed.* A perusal of the following pages will show how little has hitherto been done in this respect, and how much may be expected from it.

Nothing is more certain, I think, than that labour in free countries is cheaper than in those in which slavery exists. Labour is not to be estimated solely by its cost, but by the results obtained from it. In

England the wages given to workmen in certain branches of manufacture are considerably higher than those paid to the same class of workmen on the continent of Europe; and yet, if the respective sums be measured by their results, it will be found that labour is cheaper in the former country than in those of the latter. Ask a London sugar-refiner, "Which would be the most remunerative to him, the requisite number of negroes to carry on the process of sugar-boiling as at present practised in the colonies, free from all charge except their maintenance; or the requisite number of skilled workmen, receiving the usual rate of wages, to carry on the work of a well-appointed refinery?" Or ask a farmer, "Whether he considers the maintenance of one hundred human beings, men, women, and children, for the purpose of cultivating an equal number of acres of land, as remunerative as the means he now employs?"

We ought to be proud and thankful that the odium of slavery does not now attach itself to the British people; and it is to be regretted, although scarcely to be expected, that the injurious systems begotten during the period of its existence were not abolished at the same time.

An attempt to continue the same modes of agriculture and manufacture with a free people, and, therefore, by money payments, as are in operation in countries where slavery is established, must necessarily entail a ruinous competition, however

numerous the labouring population may be. Barbadoes, for instance, with all her advantages of climate and soil, and with available field labour in proportion to extent of surface, numerically double that of England, cannot, while the old systems are pursued, produce sugar at the price for which it can be grown in Cuba and Brazil; and a competition with them would, it is evident, under such circumstances ultimately prove a very destructive one to her.

But can any one suppose that such will always be the case? Can it be imagined that some exception is made to the West Indies, and that there alone, of all parts of the world, the struggle between free labour and that of slaves must necessarily remain, as it certainly is now, a disadvantageous one to the former?

That the struggle may be successful to the British planter, it is manifest that he must attain his purpose at the least possible expense; to effect which a thorough knowledge of his art, as well as the judicious application of the labour which he may command, are essentially necessary.

The object of the following work is to supply him with the means of acquiring a knowledge of those principles which ought to guide him in the art of making sugar, — a want that has long been felt. I have confined myself exclusively to this subject, and if I have not alluded to the sister branch of agriculture, it is not from considering it less im-

portant, but because its general principles will be found in works of much higher authority, and their application to tropical countries has formed the subject of an admirable little book by Dr. Phillips.

How far my object has been fulfilled I leave my readers to judge. I can at least assure them that I have spared no pains in my attempt. If I succeed in infusing among planters a spirit of inquiry into those branches of science which are closely associated with their pursuits, or if I excite the interest of some better qualified person than myself on a subject of such vast importance to our intra-tropical colonies, I shall be amply satisfied.

London, July, 1847.

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THE

SUGAR-PLANTER'S MANUAL,

&c.

PART I.

CHAPTER I.

PLANTS, THEIR MODE OF GROWTH AND DEVELOPMENT. — PROXIMATE VEGETABLE PRINCIPLES. — NON-AZOTIZED. — AZOTIZED. — CATALYSSIS. — SALTS.

To prosecute with success any branch of art or manufacture, a knowledge of the principles on which the art or manufacture is based is indispensable. It will, I think, be admitted, that of two persons pursuing the same industrial occupation, the one who brings to his assistance an acquaintance with the laws by the operation of which the effects sought to be obtained are governed, will possess advantages over the other, and that his efforts will present a greater chance of success.

The object of the sugar-maker is that of separating from *cane juice*, a fluid composed of a great

variety of substances, one of its components, *sugar*, in the greatest abundance and most marketable form. This operation is essentially a chemical one; and although it may not require that the person performing it should be a chemist in the full sense of the word, yet some acquaintance with that science would prove beneficial to him in many respects.

It is owing to the cultivation of the beet-root, and the art of extracting sugar from its juices having fallen immediately under the observation of the chemists of Europe, and having, consequently, received all the assistance that science could bestow, that that branch of industry has made, within a few years, such a great and rapid development; whereas, on the other hand, it is chiefly from the want of such aid that the sister art in the colonies remains to this day almost in its primitive state. Far removed from the sphere of European science, the planter cannot avail himself of the advantages of its immediate assistance at any moment that he may require it; he must trust exclusively to himself and his own resources in every emergency that may arise; therefore, an adequate knowledge of his profession is even more necessary to him than to those who follow a corresponding occupation in Europe.

That the reader may more clearly comprehend the principles on which the manufacture of sugar is based, I shall lay before him a slight sketch of a few of the *chemical and physiological* facts from which they have been deduced. To enter as fully as I could desire upon a subject so interesting would require a space far beyond the limits of a work like

the present: I must, therefore, refer those who are desirous of prosecuting it to other sources of information.

The more perfectly organised vegetables consist essentially of three parts—the root, the stem, and the leaves. By the root the plant is fixed in the soil; whilst its stem, branches, and leaves are expanded in the atmosphere. The organs which enter into the formation of the stem are the *cellular tissue*, the *vessels*, the *woody fibre*, and the *bark;* but they are found arranged in a different manner in the two subdivisions of the phanerogamiæ, or flowery plants. In *exogens* these parts are separated by distinct lines of demarcation. The cellular tissue is in the centre, in the shape of the pith, and in the medullary rays, which, diverging from the former, run towards the circumference. Around the pith are placed the vessels and woody tissue in concentric circles. These are surrounded by the bark which is very distinguishable and easily separated. In the *endogens* the cellular tissue is diffused through the entire stem, the vessels and woody fibre being dispersed irregularly through it; and the bark, instead of being slightly attached to the parts within it, can be with difficulty distinguished, owing to its being gradually blended with them.

The roots as they leave the lower part of the stem present a similar structure to the stem itself, but towards their extremities they consist merely of bundles of vessels surrounded by white, soft, and spongy cellular tissue. It is by these spongy ex-

tremities that the liquid and gaseous matters enter into or escape from the interior of the root.

The branches, when they exist, are mere expansions of the stem; and the leaves may be considered as a still further extension of these parts, for the vessels and woody fibre are continued into them. Interspersed through the leaf and between the ramifications of its fibres is a cellular tissue and a green colouring matter, called *chlorophylle.*

It is obvious that a plant must receive its nourishment either from the soil in which it is fixed by its root, from the atmosphere by which its stem, branches, and leaves are surrounded, or from both sources. Numerous experiments have established that the latter is the case.

All soils consist essentially of inorganic salts, some of which are soluble, others insoluble, in water; variable proportions of organic matters; and of water, holding in solution a little of the former and certain gases, particularly carbonic acid and ammonia, which result from the decomposition of the latter. Carbonic acid is composed of the two elements *carbon* and *oxygen*, and ammonia of the two elements *hydrogen* and *nitrogen.*

The atmosphere consists of a mechanical mixture of nitrogen, oxygen and carbonic acid, in the proportion of 75·55 parts by weight of the first, 23·32 parts of the second, and 0·1 part of the last in 100. To these is added a variable quantity of watery vapour.

If these be the only sources whence vegetables can obtain their nourishment, it follows that what-

ever be the substance produced by the vital processes going on in plants, its chemical composition must consist of a combination of one of the four elements, oxygen, hydrogen, nitrogen, and carbon.

The water holding some of the fore-mentioned substances in solution is absorbed from the soil by the spongy extremities of the root. Thus combined, it constitutes what is called the crude sap, which is ultimately carried by the vessels of the stem to the leaves, where it undergoes a great change. In the first place a large portion of it is eliminated by a process called *exhalation*, and which resembles that of perspiration in man. Secondly, the carbonic acid is decomposed, the oxygen being set free and evolved into the atmosphere, while the carbon remains; and, lastly, a quantity of carbonic acid is likewise absorbed from the surrounding atmosphere, which is likewise decomposed in a similar manner.

These processes are very much expedited by solar light and heat. During night the evolution of oxygen by the plant ceases, indeed, the reverse takes place, for it now emits carbonic acid and absorbs oxygen. Still, as a general rule, the quantity of carbonic acid given off during night is far from being equal to that which is absorbed during the day.

The sap having thus been deprived of a great portion of its water, and its carbonic acid having been converted into carbon, has necessarily undergone a great chemical change; and being now fitted for the purposes of nutrition, it commences its descent through the stem.

Besides the power of absorbing fluids and gases, the root possesses the faculty of separating from the sap certain excrementitious substances not essential, probably injurious, to its nutrient qualities. From this cause soils are often impregnated with matters excreted by one kind of plant which may materially affect others which have been subsequently grown upon it.

It is this faculty that vegetables possess of extracting their nourishment from inorganic matter, that constitutes the great characteristic distinction between them and animals. Plants may, therefore, be considered as the great purveyors of food for the whole animal creation, every member of which, either directly or indirectly, depending upon them exclusively for its supply.

If what I have stated be true, animals and vegetables must necessarily be composed of the same ultimate elements, and such, indeed, is found to be the case; and in the great operations of nature each of these two classes of created beings mutually provides sustenance for each other.

All organic substances, that is, all substances which owe their origin to vital action, whether obtained from the animal or vegetable kingdom, are composed of four elementary bodies only, namely, oxygen, hydrogen, carbon, and azote or nitrogen; two others only, sulphur and phosphorus, being occasionally associated with some of their compounds.

This paucity of ultimate elements is compensated by the wonderful property which the four first mentioned possess of forming with each other al-

most innumerable combinations. We see the result of these combinations hourly in all the various products of the organic world; in that incomprehensible centre of human thought and intellect, the brain of man; in the structure of the most simple cell which constitutes the earliest rudiment of vital tissue; in the hardest timber, or in the soft and fragile mould and mildew. Now we view them in the form of crystal; at another time as a powerful acid; again as a bland and liquid mucilage, or as the most intense of the known poisons.

The affinities which bind these elements together in all such compounds are weak and easily disturbed when the force by which they were originally produced has ceased to exist, and the laws of inorganic matter have come into play. The carbon and oxygen then have a tendency to combine and form carbonic acid, and hydrogen and nitrogen to form ammonia.

All the proximate principles which enter into the structure of a plant are formed by a blending together of these elementary bodies in various proportions; but as some of them contain nitrogen and others do not, they are divided accordingly into the non-azotized and azotized proximate principles.

The non-azotized proximate principles of vegetables are very numerous. They are subdivided into those in which the carbon is united to the oxygen and hydrogen, in the proportion of each necessary to form water; and into those in which this proportion of the two latter elements is not observed.

Of the former, those which offer the greatest interest to the planter are the following: *dextrine*, *starch*, *cellulose* or cellular tissue, *lignin* or woody fibre, the various *gums*, *mucilage*, and *sugar* of different kinds.

Dextrine is an essential component of the sap of all plants. As it possesses the same chemical composition as starch and gum, and many of the physical properties of the latter, it has been frequently confounded with it; but there is one essential difference between the two, that dextrine is capable of being converted into sugar by the action of sulphuric acid or diastase, but gum does not possess this property. Gum, too, may be considered more in the light of an excretion or exudation on the surfaces of plants, than an essential component of their juices.

Dextrine would appear to be the source whence the greater number, if not all the organs of a plant are formed. We are justified in assuming that the sap contains in solution the substances necessary for the construction of the entire fabric of the vegetable. The only materials whose nature admits of their solution, of all those found in vegetable non-azotized bodies, are dextrine and sugar; but many full-grown plants contain an amount of sugar quite insufficient for the purpose, while dextrine is found in all. There are, however, exceptions; for instance, in the sugar-cane the quantity of sugar is incomparably greater than that of dextrine, particularly when the plant has acquired a certain age. But even in this case it is

not improbable that the sugar may be converted into dextrine previously to its ultimate conversion into the other tissues.

The chemical composition of dextrine is comprised in the formula: carbon, 12 atoms; oxygen, 10 atoms; and hydrogen, 10 atoms. As the amounts of the two latter elements are equal to 10 atoms of water, dextrine may be said to be composed of 12 carbon + 10 water.

Starch. This proximate principle is very generally diffused through the vegetable kingdom. When removed from the plant in which it has been formed, it is found to consist of minute granules, each of which, when viewed under the microscope, has the appearance of a globular or spheroidal cell, and is composed of a substance very analogous to gum, enclosed in a thin, but very firm envelope, to which its consistency is owing. These grains resist the action of many chemical re-agents; but when exposed to a heat of 180°, the pellicle bursts, and its contents are liberated. This is the explanation of the fact that starch dissolved in hot water can never be restored to its original form. When in this state of solution it is quickly converted into dextrine by the addition of a small quantity of sulphuric acid or diastase, a substance presently to be described. If this mixture be boiled for some time it gradually acquires a sweet taste, from the conversion of the dextrine into one of the varieties of sugar, *glucose.*

Starch forms a large proportion of the weight of those seeds and roots employed by man as food.

Its use in the economy of the plant appears to be as a dépôt of nourishment set by for its future exigencies, being admirably adapted to the purpose from its easy conversion into dextrine or sugar. We have an interesting example of these changes in the germination of seeds. The composition of starch is identical with that of dextrine.

Gum. The variety of gum with which we are best acquainted is the produce of several species of acacia. It exudes from the branches and stems of these trees, and is collected in rounded drops or tears. A substance closely resembling it in every respect results from changes produced by certain re-agents on sugar. Gum, however, that is, the substance known as gum-arabic, cannot be converted into sugar by any means with which we are acquainted. Its composition is the same as that of the before-mentioned proximate principles.

Mucilage is closely allied to gum in many of its properties. It enters into the formation of certain parts of many vegetables, as in linseed, quince seed, in the roots of the mallows, &c., and is the chief constituent of gum-tragacanth. By the addition of sulphuric acid, it is convertible into glucose, or the sugar of fruits. According to Mulder, its composition is, carbon, 24; oxygen, 19; hydrogen, 19; or carbon, 24 + water, 19.

Cellulose. This proximate principle constitutes the cellular tissue of all plants. Mulder states that in combination with the incrusting matter, which is deposited upon the cells, woody fibre, and vessels, for the purpose of adding to their strength and

powers of resistance, it enters into the formation of all these parts. It consists of 24 atoms of carbon, united to 21 atoms of oxygen, and 21 atoms of hydrogen; or carbon, 24 + water, 21.

Woody-fibre, obtained from newly-cut wood which has been boiled in successive portions of water and alcohol, according to Dr. Prout, is composed of carbon, hydrogen, and oxygen, in the proportions required to produce the formula: carbon, 12; hydrogen, 8; oxygen, 8; or carbon, 12 + water, 8.

Whether woody-fibre or lignine, as it is sometimes called, is really a substance different from cellulose, as the composition of each as given above would lead us to believe, or whether these differences of composition may result from a combination with some other matter in one case which does not exist in the other, it would be difficult to say; nor is it necessary for our purpose to inquire. They are both composed of carbon + water, the ratio which the one bears to the other being the only difference observed.

Sugar. This substance is not exclusively found in the vegetable kingdom. Two of its varieties are found in excretions from animal bodies, namely, the sugar of milk, and that obtained from the urine of patients labouring under a peculiar disease. A third variety can be obtained from the gelatinous tissues of animals, by the action of sulphuric acid; but as it differs from all the others in containing a small quantity of nitrogen, it is questionable whether it deserves a place in the category of these substances. The principle kinds of sugar found in

vegetables are three, namely, cane-sugar, glucose or the sugar of fruits, and mannite or the sugar of manna.

Glucose. It is to this variety of saccharine substances that most of our well-known fruits owe their sweetness; it is the sweet principle of brewers' wort, and is also found in many other vegetable substances. Although it possesses many of the properties of cane sugar, it, nevertheless, has other important peculiarities, which render it easily distinguished: first, it is uncrystallisable; secondly, it undergoes the vinous fermentation with great readiness; and, lastly, it has a different composition, consisting of 12 atoms of carbon, 12 of hydrogen, and 12 of oxygen+2 atoms of water, with which it is combined as with a base, and which it loses when it enters into combination with other bases. As found in nature in the state of a hydrate, or, in other words, combined with its basic water, it consists of carbon 12+water 14.

Mannite. This is the chief ingredient of manna, an exudation from a species of ash; it is also found in the juices of many other plants, particularly in those of New South Wales, and in certain sea-weeds. Cane sugar, when in a peculiar state of fermentation, is partially converted into it. Mannite crystallises in tufts of slender colourless needles. It cannot be made to undergo the vinous fermentation. According to Dr. Prout it is composed of carbon, 15 atoms; hydrogen, 16 atoms; and oxygen, 16 atoms; or carbon, 15+water, 16 Whether any of this water is basic is unknown.

Cane Sugar. It is this variety of sugar that constitutes the substance so well known under this name. As a detailed account of its chemical and physical properties will be given hereafter, it will be sufficient, at present, merely to state its composition, which consists of carbon, 12 atoms; hydrogen, 10 atoms; and oxygen, 10 atoms + 1 atom of water with which it is, in its ordinary condition, always combined as with a base. It may be then said to be composed of carbon, 12 + water, 11.

A glimpse at the following table, in which the names and composition of the proximate principles described above are placed in juxta-position, will show us the chemical resemblance they bear to each other, and enable us to understand how bodies so dissimilar in their physical properties may be mutually converted into each other from slight disturbing causes: —

Dextrine consists of	-	carbon	12	+ water	10
Starch	-	-	-	12	+ -	10
Gum	-	-	-	12	+ -	10
Cellulose	-	-	-	24	+ -	21
Lignine	-	-	-	12	+ -	8
Mucilage	-	-	-	24	+ -	19
Glucose, or sugar of fruits			-	12	+ -	14
Mannite	-	-	-	15	+ -	16
Cane sugar	-	-	-	12	+ -	11

It is evident the conversion of any one of these bodies into any of the others is effected by the addition or subtraction merely of a small quantity of the elements of water. Thus, by the addition of three atoms of water, cane sugar is converted

into glucose, and by a still less amount it may be transformed into dextrine.

These operations are continually going forward during the life of every plant, and many of them are daily performed in the laboratory of the chemist. By the action of heat, saw-dust may be conconverted into a nutritious substance, capable of undergoing the vinous fermentation, and which has all the chemical properties of starch. Sulphuric acid likewise produces a similar effect upon it.

When starch is exposed in an oven to a temperature of 300°, it is converted into a substance called British gum, which is extensively employed in the arts: it is dextrine. When starch is boiled with sulphuric acid, glucose is produced. This constitutes an extensive manufacture both in France and Germany, the syrup thus prepared being used for the purposes of brewing and distilling.

These are but humble imitations by man of the great transformations effected by nature in the growth and development of all vegetables. To be able to understand more clearly how these wonderful effects are produced, it will be necessary to examine the other proximate principles of plants into the composition of which nitrogen enters as an essential element.

The azotized proximate Principles.

Although the *mass* of vegetable fabrics consists of carbon, hydrogen, and oxygen, there are other principles found in some part or other of all plants which require nitrogen for their formation. As compared with animals the amount of these substances, it is true, is but small, but their presence is not the less necessary; for some of the most important functions of the vegetable economy could not be performed without them. Nitrogen is found in every plant from the period of its earliest development. The substances into the composition of which this element is essential are very numerous; but those which it more immediately concerns us to examine in this place, from their universal presence throughout the whole of the vegetable creation, are the bodies which, from their resemblance to similar constituents of animals, have been denominated albumen, fibrine, and caseine, the term vegetable being prefixed to each to denote its origin.

There are also two other bodies which exist in plants, but which are not found in animals: the one is a compound of fibrine and a substance called gliadine, and known by the name *gluten*, the other is found only in germinating buds and seeds, in which it exists in considerable abundance: it is merely a modification of one of the above nitrogenised principles, and is called *diastase*. These

three first-mentioned nitrogenised principles approximate very closely in their chemical composition; indeed, they are compounds of a base *proteine* united to a very small quantity of either phosphorus or sulphur, or both. Proteine, from whichsoever of these sources it is obtained, always presents the same chemical composition. 100 parts yield —

	From albumen.	From fibrine.	From caseine.
Carbon -	55·30	55·44	55·16
Hydrogen -	6·94	6·95	7·17
Nitrogen -	16·02	16·05	15·86
Oxygen -	21·74	21·56	21·81
	100·	100·	100·

These numbers give the empirical formula: carbon, 40; hydrogen, 31; nitrogen, 5; oxygen, 12.

Vegetable albumen. The substance to which this name has been applied is a compound of proteine, containing in 100 parts 0·33 part of phosphorus, and 0·68 part of sulphur. The white of an egg, or the serum of the blood, will give us an idea of this body as it is found in animals. In vegetables it is found in almost all parts of their structure. It occurs largely in their fresh juices, from which it can be thrown down in a solid form by many re-agents.

When exposed to heat, albumen solidifies or coagulates, but the temperature required to produce this effect varies with the amount of the substance dissolved. If the amount equal that contained in the white of an egg, 145° of heat suffices; but if the solution be very dilute, boiling is

required, and the albumen then separates in the form of a light white flocculent precipitate. The soluble salts of lead, tin, bismuth, silver, and mercury form insoluble compounds with albumen, and thus throw it down from its solutions. The diacetate of lead has the power of effecting this entirely. The mineral acids also precipitate it more or less, particularly the sulphuric, nitric, and metaphosphoric. Alcohol and infusion of galls produce a similar effect.

In dilute caustic alkali albumen dissolves with facility.

The second variety of proteine compounds found as a proximate principle in vegetables is *fibrine*. This substance, as already stated, exists in a solid form, often combined with gliadine, in the seeds of certain plants. It is also found in solution in their juices, from which it is seen to separate in thin thready fibres, when removed from the influence of the vital action. It contains 0·33 part of phosphorus, and 0·36 part of sulphur in 100.

The third proximate vegetable principle containing nitrogen, is likewise a proteine compound. From its similarity to the characteristic azotised component of milk, it has been denominated *caseine;* and from its existence in considerable abundance in the seeds of leguminous plants generally, as in peas, beans, &c., it is sometimes called legumin. It is also found in solution in most vegetable juices. Its solubility, however, is owing to the presence of an organic acid, or an alkali; for in pure water it is perfectly insoluble. As it exists in milk, it is

rendered soluble by a certain amount of free alkali, which is likewise present in this fluid; and on the addition of an acid which can destroy this combination, the caseine, being no longer soluble, is separated in the form of curd. In vegetable juices for the most part this substance is kept fluid by the presence of an acid; the addition of an alkali or alkaline earth, therefore, is required for its precipitation. This explains in some measure the use of lime in the clarification or defecation of cane juice. It also teaches us that the amount of lime required is that which is sufficient, *and no more*, to render the liquid neutral. Heat alone is incapable of coagulating caseine, or precipitating it from its solutions, the only effect produced by its action being the formation of a thin skin or pellicle on the surface of the fluid, as we see in milk when thus treated. Infusion of galls separates it from its solution more or less completely, in the form of a brownish precipitate. Diacetate of lead, sulphate and muriate of lime, the hydrates of alumina, and most of the metallic oxides when in a nascent state, produce even more completely this effect. One hundred parts of caseine contain 0·36 part of sulphur. Phosphorus does not appear to enter into its composition.

Diastase. This name has been given to a nitrogenised substance, which is soluble in water, and which is found in germinating seeds, and buds in the act of development. It is merely a modification of one of the above azotised proximate principles, and can be obtained from any of the before-

mentioned sources, by infusing it in cold water. Its use in the economy of the plant has been ascertained by direct experiment. If a little infusion of malt or germinated barley be mixed with a large quantity of thick gelatinous starch, and the whole be maintained at a temperature of 160°, a complete liquefaction takes place in the space of a few minutes. On evaporation a yellowish white powder is obtained, perfectly soluble in water: it is dextrine. If the operation be continued for a few hours, the mixture acquires a sweet taste; and if it be now evaporated, it will yield glucose, or the sugar of fruits.

From this experiment it is evident that by the action of diastase, starch can be converted into dextrine and one of the varieties of sugar.

Starch, as I have stated, from its insolubility in water, is incapacitated from performing any *active* function in the vegetable economy. It may be considered merely as a store of aliment set by for the future exigencies of the plant. Wherever it is found, (and be it remembered its existence in vegetables is far from being universal) it is sooner or later associated with diastase, under the influence of which it is rendered soluble, in the form of dextrine or sugar, by which means only can it be fitted for the purposes intended by a provident nature. Thus transformed, it becomes a nutritious principle, from which the vessels, woody-fibre, and cellular tissue are produced; or it may again be deposited in its original form. How wonderful are all these

phenomena, and how admirably adapted to the great purposes of creation!

The quantity of diastase requisite to produce these changes is very small, one part of this substance being capable of converting two thousand times its weight of starch into sugar.

The transformations above described are effected in a very different manner from those which are produced by ordinary chemical actions. In the latter case, where decomposition is effected by the interposition of a new agent, it is by the superior attraction of that agent for one of the elements of the former combination. Thus, when sulphuric acid is poured upon carbonate of lime, the carbonic acid is liberated and the sulphuric acid takes its place, forming the new compound, sulphate of lime. But in the changes which we are examining, whether produced by heat, sulphuric acid, or diastase, no such substitution of the disturbing agent occurs; for neither the heat, nor the acid, nor the diastase, are found to have combined with the elements of the substance acted upon. To distinguish this class of actions from those of ordinary chemical affinity, Berzelius has given it the appellation of *catalyssis*. To the planter a clear understanding of them is essential; for it is in consequence of the molecular changes thus induced in the component elements of the sugar, that nearly all the evils which occur during the process of its manufacture arise.

I have stated that diastase is merely a modification of one of the compounds of proteine above named; that such is the case seems proved by its

possessing a similar composition, and by the identity of their actions. We have seen that diastase has the power of converting starch into dextrine and glucose. If it be kept, while moist, in a warm place for a few days, it loses this property, but has acquired a new one, namely, of converting glucose into lactic acid. When kept for a still longer period, it acquires the properties of the common yeast, and induces in saccharine fluids the vinous fermentation. The albuminous principles of vegetables and animals produce the same effects under similar circumstances. They, moreover, produce others which I have not yet mentioned, but which it is highly important should be known to the sugar-maker, and which are interesting as examples of the variety of changes induced by this class of actions.

If a solution of refined cane sugar in water be exposed for a few hours to a temperature approaching 200°, the cane sugar is converted into the sugar of fruits; if the experiment be continued, the solution acquires a dark colour, and ultimately a dark brown powder falls, which does not possess sweetness; it is one of the substances which has been described as ulmine and ulmic acid. If glucose be similarly treated, but with the addition of a little lime, a similar precipitate, but of a still darker colour, is quickly induced. It is a combination of glucic and melasinic acid with the lime. The lime has acted as an oxidising agent, and converted the glucose into glucic acid, with which it has immediately united, and by the prolonged action of this

elevated temperature the glucic acid is converted into melasinic acid. The respective composition of these two bodies will enable us to understand the change which has been produced in the glucose. Glucic acid consists of carbon 8, hydrogen 5, oxygen 5; and melasinic acid of carbon 12, hydrogen 6, oxygen 5.

If a little gluten, obtained from wheat, be placed in contact with a solution of cane sugar, and the mixture be exposed to a moderately high temperature, it becomes viscid and mucilaginous; its sweetness disappears, and on examination gum will be found to have occupied the place of sugar.

If a little curd, or a piece of animal membrane, or a small portion of gluten which has been preserved for a short time, be added to a solution of cane sugar, the latter is converted into mannite and lactic acid.

If the above substances, or blood, or white of egg when the putrefactive decay has fairly commenced, be added to a solution similar to the above, the vinous fermentation will be established, the sugar, however, being previously converted into glucose by the action of these substances. It may be necessary to mention that, whenever this last-named change is produced in saccharine liquids, it is invariably accompanied with the development of myriads of minute cryptogamic plants, each individual of which consists of a simple nucleated cell. They are endowed with great fecundity, and continually increase in number until the fermentation is at its height. How far their existence may be

essential to the development of this change is a question which has latterly been much agitated, but which it is unnecessary for our purpose to discuss.

The term fermentation has not been confined to this last-mentioned metamorphosis of saccharine substances, but has been applied equally to the others produced by the like class of causes. Thus the one in which the sugar is converted into gum, has received the appellation of the *viscous*, and that in which the same body is converted into lactic acid, has been denominated *the lactic acid fermentation.*

The saline or inorganic constituents of plants. Although the great bulk of the solid parts of every vegetable is principally built up of organic substances, produced by the operations of the vital principle on the elements which have just been described, yet a small amount of inorganic matter is essential to the perfect structure of every plant.

When, from the application of heat, the organic constituents have been dissipated, the only remains of a plant are found in a small amount of ash. This ash constitutes the inorganic constituents which had entered into the structure of the plant during its life.

From numerous experiments that have been made upon the inorganic constituents of a great variety of vegetable bodies, the following conclu-

sions have been arrived at. I quote the words of Professor Johnston :—

"1. That on whatever soil a plant is grown, if it shoots up in a healthy manner and fairly ripens its seed, the quantity and quality of the ash is, generally speaking, nearly the same; and 2. That though grown on the same soil, the quantity and quality of the ash left by no two species of plants is the same; and that the ash differs more widely in these respects, the more remote the natural affinities of the several plants from which it may have been derived. Hence there is no longer any doubt that the inorganic constituents contained in the ash are really essential parts of the substance of the plant, and that they cannot live a healthy life or perfect all their parts without them." We must likewise conclude that the root by which these substances are absorbed must possess the power of selecting those among them which are useful to the economy, and of rejecting others, which are either not necessary, or which might prove injurious. Such a conclusion, however, must be considerably qualified. It is true that of two substances dissolved in water some plants will take up one, and some the other; but there are other substances as highly poisonous to vegetables as their absorption into the system would prove to man or animals, which are taken up by the roots of most plants without any apparent difficulty. So that we cannot allow that vegetables possess these powers of selection, except under very considerable restrictions. Practice, indeed, has demonstrated, and also taken advan-

tage of the knowledge, that some vegetables, at least, when placed under circumstances favourable to their performance of this function, absorb from the soil a quantity of the different kinds of saline matter more than sufficient for their support and nourishment.

The beet-root which has been cultivated in the highly manured grounds of the market-gardener, is very large, and its growth is vigorous; but it is useless to the sugar-manufacturer, owing to the great amount of saline substances, particularly, as might be supposed, the nitrate of potash, which it contains.

Turnips which have been raised upon soils manured with the biphosphate of lime, always contain a larger amount of the phosphates than those which have been grown on land less rich in these salts, and are consequently better fitted for the food of young animals.

The sugar-cane also absorbs with great readiness the chlorides of sodium and potassium, and probably the sulphates of these bases likewise. So that it is not uncommon to find the juice obtained from canes which have been grown on soils in which these salts are abundant, to possess very purgative qualities, in consequence of the presence of these substances in much larger quantities than usual. The chloride of sodium (common salt) forms a highly deliquescent compound when combined with sugar; which accounts for the difficulty that attends the conversion of cane juice that contains this salt even in moderate quantity, into

sugar that will crystallise freely or "that will bear the sea."

These saline constituents are not equally diffused throughout all parts of the plant. In the sugar-cane, for instance, they constitute four per cent. of the weight of the leaves, whereas in the stem their amount generally does not exceed 0·6 per 100.

I trust that I have rendered the foregoing sketch sufficiently intelligible to the reader to enable him, on a careful perusal of it, to understand the transformations which the non-azotised vegetable principles therein named, are liable to undergo from slight disturbing causes. It will be remembered that those changes were described as being molecular ones, or at most, that they were effected by the displacement or addition of an atom or two of water, or rather the elements necessary to form those atoms to the original substance; and that of all agents none more effectually produce them than the contact of one of the azotised principles which have been described. On a knowledge of these changes is based one of the most important principles that are to guide us in the manufacture of sugar.

CHAP. II.

CANE SUGAR — ITS PHYSICAL AND CHEMICAL PROPERTIES — ACTIONS OF RE-AGENTS ON. — MOLASSES. — TREACLE.

THE substance, the nature, and properties of which it is our purpose to investigate in the present chapter, is the one denominated by chemists cane sugar, or crystallisable sugar. It is the ordinary sugar of commerce.

The presence of this non-azotised proximate principle is not confined to the sugar-cane, as the name usually given to it would indicate, although it was from this source alone that Europe was supplied with it for many ages; but it is likewise found in the stalks of many grasses, particularly in those of the maize and guinea-corn, in the roots of the carrot, beet, &c., in pumpkins and melons, in the sap of the palm, and in most of the tropical fruits, from all of which, and also from other sources, it has been obtained by the chemist; but the sugar-cane, the Silesian beet-root, the sugar-maple, and the palm, are the only plants resorted to for this purpose by the manufacturer.

From whatever plant it may have been obtained, cane sugar, when separated from its accompanying impurities by a process of refining, is physically and chemically identical. Although, when in that

state of admixture with other foreign substances that constitutes what is called moist or muscovado sugar, its origin is readily recognised.

Cane sugar, when pure, is solid, transparent, and colourless. It crystallises from its watery solution in oblique rhomboidal prisms; but if to the solution certain foreign matters be added, as alcohol for instance, the form of the crystals is very much modified. When bruised in the dark, it is seen to possess phosphorescent properties, and becomes luminous.

It is soluble in one half of its weight of water at the temperature of 60°, and in one fifth of its weight at the boiling point. It is sparingly soluble in alcohol when cold, but boiling alcohol will dissolve $\frac{1}{15}$ of its weight which it deposits on cooling.

The specific gravity of *anhydrous* cane sugar is calculated at 1600, that of water being 1000; but as in its natural condition it always contains water in combination, and, moreover, as it is found that sugar, when dissolved in water, undergoes an augmentation of volume of about $\frac{1}{15}$ of its original bulk, the density of its solutions is much less than the above figures would lead us to expect. The *apparent* density of sugar differs much, owing to a variety of causes. Thus the refined sugars of France are much more loose and spongy in texture than those which have been refined in this country, and therefore they appear to possess a lower specific gravity; but these qualities are given to them expressly to suit the wishes of the respective customers.

It has been already stated that the composition of cane sugar consists of 12 atoms of carbon, 10 atoms of hydrogen, and 10 atoms of oxygen, combined with 1 atom of basic water, which is displaced when the sugar enters enters into combination with other bases. The atomic weights of these elements are: hydrogen, 1; oxygen, 8; and carbon, 6; hence C 12 = 72, H 10 = 10, O 10 = 80, must give 162 as the equivalent or combining number of 1 atom of anhydrous sugar. Water is composed of 1 atom of oxygen, united with 1 atom of hydrogen, consequently its atomic weight must be equal to 9.

The proximate vegetable principle, cane sugar consisting, as has been shown, of 1 atom of anhydrous sugar = 162 + 1 atom of water = 9, it necessarily follows that its atomic weight must be 171; that in every 100 parts it must contain 5·3 of water; and that its specific gravity must be 1600 less $\frac{5 \cdot 3}{100}$ of water, and less $\frac{1}{15}$ of the bulk of the sugar allowed for its expansion when dissolved in water.

Cane sugar, like all other organic substances, undergoes decomposition from slight disturbing causes. When pure, however, it is not prone to undergo any chemical change by mere exposure to the atmosphere: we have an instance in ordinary refined sugar which may be kept for an indefinite period without alteration.

A syrup obtained by dissolving two parts by weight of very pure cane sugar in one part of water may be kept for some time without under-

going any change; but at length it acquires a somewhat darker colour, and a portion of it, by combining with the elements of water, is slowly converted into glucose. But if it be exposed to a temperature of 180° or 200°, either in a closed vessel or exposed to the atmosphere, this change is produced in a very few hours. If the syrup be exposed to this degree of heat for ninety hours, it becomes black and acid, and a dark brown powder will be found at the bottom of the vessel.

These changes are much expedited by the presence of an acid, even when its amount is very small; on the contrary, they are retarded by the presence of lime. But if the cane sugar be not pure, if it be combined with glucose even in a minute quantity, lime has a contrary effect, and rather hastens than retards them.

The explanation of these phenomena is as follows: the sugar is first converted into glucose by combining with two atoms of water; this change is accelerated by the presence of an acid, which acts in the way formerly mentioned. The glucose in its turn is converted into glucic acid and melasinic acid. Lime or an alkali promotes this result, and when produced it immediately enters into combination with the newly formed acids. The composition of glucic acid is, as has been shown, C 8, H 5, O 5 = carbon 12 + 7·5 water; that of melasinic acid is C 12, H 6, O 5, = carbon 12 + 5 water + 1 hydrogen.

These changes, therefore, are produced first by the addition to, and subsequently by the sub-

traction of the elements of water from the original cane sugar of the syrup.

At the temperature of 300° cane sugar melts, and forms on cooling a glassy uncrystallised mass, known as barley-sugar. After some time this substance evinces a tendency to crystallise; but if the temperature be continued for seven or eight hours, the properties of the sugar are permanently changed, and its crystallising power is gone.

When the temperature is raised a few degrees beyond this point, decomposition *visibly* commences, water escapes in the form of vapour, and a dark brown mass remains.

If exposed to a temperature of 400°, the sugar is converted into a blackish-looking substance, which is very soluble in water, and which deliquesces on exposure to the atmosphere. It consists of hydrogen 5·9, oxygen 46·6, carbon 47·5 parts in 100, and consequently corresponds with the formula, carbon 12 + water 9, or the original sugar less two atoms of water. In ordinary language it is said that the sugar which in whole or in part has undergone this change in consequence of its exposure to a too elevated temperature is *carbonised;* an expression sufficiently explicit of the transformation which has taken place.

When the sugar is rapidly heated to 500° or upwards, a black substance having a bitter sweet taste is formed; water, the formic and acetic acids, and carbonic oxide, being at the same time evolved. This is the substance known by the name of caramel; it is a compound of sugar which has been

more or less altered, ulmic acid (carbon 12 + water 6), melasinic acid, and charcoal.

Cane sugar submitted to destructive distillation in a closed retort, emits a large quantity of inflammable gases, and an almost pure carbon or charcoal remains. This, on incineration, leaves a few ashes which consist of the inorganic salts contained in the sugar.

When a solution of cane sugar is mixed with one of sulphate of copper, if caustic potash be added in excess, a deep blue liquid is produced, which, on the application of heat, undergoes little or no change immediately. But if a solution of glucose, or the sugar of fruits, be treated in a similar manner, on the first application of heat it throws down a copious precipitate of a greenish colour, which rapidly changes to scarlet, and eventually to dark red, leaving merely a colourless liquid above. This is an excellent chemical test for distinguishing the two varieties of sugar, or discovering an admixture of their solutions.

If a saturated solution of cane sugar be heated in contact with a quantity of caustic potash, ulmic and formic acids are produced, which unite with the potash and form ulmates and formates of that base. The alkalies and alkaline earths, when added to solutions of cane sugar in smaller quantity, are capable of combining directly with it. From these combinations the sugar is set free in an unchanged state by the addition of any of the weaker acids; even carbonic acid will produce this effect.

The compound of sugar and lime is remarkable

for being more soluble in cold water than in hot. It has a bitter taste, and is uncrystallisable.

Sugar also forms compounds with baryta, oxide of lead, and chloride of sodium (common salt). The compound of cane sugar with the last-named substance is one of great importance in the manufacture of sugar; for, according to Peligot, it consists of one part, by weight, of the salt to six of the sugar, and is so deliquescent, that it renders liquid another portion equal in weight to itself. If, therefore, muscovado sugar contain only 1 per 100 of common salt, we may form an idea of the great injury and loss which must ensue from drainage alone, which will equal 14 per 100 of the whole.

By the action of *diluted* nitric acid cane sugar is converted into saccharic or oxyhydric acid. If the acid be concentrated, oxalic acid is produced.

Concentrated sulphuric acid decomposes cane sugar into charcoal, water, and acetic acid. When diluted, it converts it into glucose or fruit sugar, as already stated.

Chlorine and muriatic acid gas are absorbed by sugar, which they render brown and clammy.

The vegetable acids render sugar uncrystallisable.

The action of the proteine compounds upon cane sugar have been already stated. We have seen that the contact of these bodies is capable of converting cane sugar into gum, into lactic acid and mannite, into glucose, and finally, into alcohol and carbonic acid; the kind of change depending upon the state of decay of the exciting substance.

When vinegar is added to a solution of cane

sugar, and the mixture kept for a length of time at a moderate temperature, the whole will be converted into vinegar, without any sensible fermentation. The composition of vinegar being carbon 4 + water 3, it follows, that in this conversion one atom of the sugar must produce three of the vinegar or acetic acid, and one of water, which is found to be the case.

Muscovado sugar, of commerce, is sugar in the state in which it arrives from the colonies, in other words, sugar mixed up with variable proportions of foreign matters. According to an analysis made by Avequin, 20 lbs. of badly cured Muscovado sugar contained, of silica 414 grains, biphosphate of lime 351 grains, phosphate of lime 300 grains, carbonate of lime 38 grains, organic matter 875 grains, sulphate of potash 291 grains, chloride of potassium 400 grains, acetate of potash 360 grains, acetate of lime 250 grains; amounting, altogether, to about 3 per cent.

In this analysis, it is not the amount of these matters which strikes us as extraordinary, for that is not greater than the nature of the soil from which this mixture of sugar and molasses was produced would lead us to expect, nor is it greater than what is found in the best kinds of sugar which we receive from the West Indies, but it is the excess of the phosphates of lime in proportion to the quantity of the other salts which renders this result an unusual one.

West India sugars always contain a quantity of insoluble impurities, which are immediately precipi-

tated when the sugar is dissolved in water. They consist of the earthy matters which have adhered to the canes, of broken up woody tissue, of cellulose, and of coagulated albumen. Their combined amount varies from 2 to 6 per cent, the general average being about 3 per cent. The sugar, when deprived of these substances, contains chlorine, acetic acid, and sulphuric acid, lime, potash, soda, alumina, and silica, the collective amounts of which are from 0·5 to 2·5 per cent.

Molasses may be considered to be the mother liquor which is left after the crystallisation of cane-syrup. This substance must, consequently, consist of sugar in a state of solution, and of all the soluble matters contained in the cane-juice, which have not remained in the sugar, or which may not have been removed during the process of concentration. Its specific gravity is 1330 or 1340, that is about 38° to 39° Beaumé. Avequin's analysis of molasses obtained from canes grown in Louisiana gives, as a result from 20 lbs., good crystallisable sugar 15 lbs., salts and organic matter 1 lb., and 4 lbs. of water. The salts he describes as acetate of potash, chloride of potassium, sulphate of potash, biphosphate of lime, silica, and acetate of lime. And the organic matter, gum, or a substance resembling it; which, however, constitutes only $\frac{1}{9}$ of the foreign matters, and but ·65 per 100 of the whole. This analysis, however, does not agree exactly with those obtained from molasses produced from canes grown in those islands of the West Indies which have long been cultivated;

Barbadoes' molasses, for instance, contain both a much larger quantity of organic matter, precipitable by the diacetate of lead, and a much smaller amount of fixed salts.

Treacle is the ultimate product obtained after the various manipulations to which sugar is submitted by the refiner. It is a viscid and adhesive fluid of a dark brown colour, approaching to black, and has a specific gravity of about 1380 or 1400, varying from 42° to 44° Beaumé, at the ordinary temperature of England. By evaporation it becomes solid, but in a short time reverts to its original fluid state. It cannot be made to crystallise, but on repose often deposits a small quantity of a light-coloured amorphous sugar. Boiling alcohol separates from it a small quantity of crystallisable sugar, while it at the same time produces the precipitation of a considerable amount of a substance resembling gum. Cold alcohol dissolves from treacle, when dried, a compound of a dark colour, of a sweetish saline taste, and which is very deliquescent and perfectly uncrystallisable. It appears to be a combination of saline matter and a substance which will be noticed hereafter, and which is known as the "*matière deliquescente*" of Hervey. Besides these bodies, treacle likewise contains a certain amount of uncrystallisable sugar or glucose, a little mannite, and melasinic and ulmic acids, on which its intense colour depends.

CHAP. III.

SUGAR-CANE, ITS ANATOMY AND PHYSIOLOGY. — CANE-JUICE, ITS COMPOSITION — THE CHANGES PRODUCED UPON IT BY RE-AGENTS. — ALTERATIONS EFFECTED DURING THE LIFE OF THE PLANT. — THE METHODS EMPLOYED TO ASCERTAIN THE QUANTITY OF SACCHARINE MATTER IN LIQUIDS.

THE SUGAR-CANE (*saccharum officinarum*) belongs to the graminaceæ or grass tribe of plants, all of which are of endogenous growth, and are generally of very simple structure.

There are many varieties of sugar-cane cultivated in the West Indies, Brazil, Louisiana, and the Mauritius, the principal of which are — 1st, the common, or, as it is generally called, the Creole-cane, from having been the one originally introduced into the New World; 2d, the yellow Bourbon; 3d, the yellow Otaheite. The two latter are frequently confounded, and are, at present, probably from the influence of soil and climate, not easily distinguished. The other varieties are — 4th, the Otaheite with purple bands; 5th, the purple Otaheite; and 6th, the transparent or ribbon-cane, known by its dark red streaks on a clear waxy-looking ground.

To discuss the merits or demerits of each of them belongs to the province of the agriculturist. We have another object to perform, namely, that

of examining their structure and organisation; and, as in this respect they are all exactly alike, a description of one is applicable to them all.

The sugar-cane is a perennial plant arriving at maturity, or, more properly speaking, at that stage of its existence when its growth is for a short time suspended, and when it seems to evince a desire to perform another function, that of flowering or fructification, at from eleven to fourteen months after planting. This may be considered a general rule, to which there are numerous exceptions, arising from locality, moisture, soil, atmospheric temperature, &c., &c.

Of all parts of the plant, it is the structure of the stem which offers the greatest interest to the planter, as it is from this part alone that he is able to extract the sugar, the object of all his labours.

A *horizontal* section of a portion of sugar-cane which has arrived at the period of its maturity, placed under the microscope, presents the following appearance. It will be seen that its internal structure consists of a series of cells, generally hexagonal in shape, which touch each other in every direction. They are formed by a thin delicate tissue, which encloses them, not laterally merely, but both above and below; so that each is perfectly closed and separate from those adjoining. No communications by pores, or otherwise, can be discovered between them when examined under the highest power.

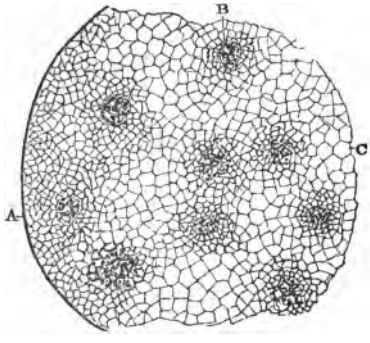
This structure is called the *cellular structure.* It exists in all plants, and the tissue of which it is composed is the one already described as *cellulose.*

When the plant is young this tissue is very soft and yielding, but as it advances in age it becomes more firm and rigid, from the incrustation of its surface by a substance, called by Payen "*la matière incrustante.*"

Interspersed through the structure are a number of vessels running in groups of two, three, or four, each of which is enclosed in a sheath of woody fibre.

Surrounding the whole stem is the cortex or bark, covered by its coating of silica. It is not separable, or indeed scarcely distinguishable from the internal structure just described.

The accompanying sketch will give us an idea of the appearance presented by such a section of sugar-cane when placed under the microscope, A being the bark or rind, B a bundle of vessels enclosed in their common sheath of woody fibre, and C the cells.

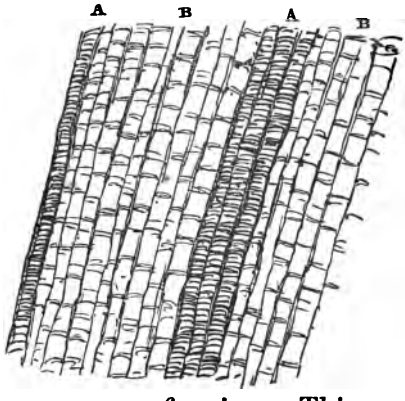


If the section be made from a part of the cane which is not as yet become mature, the cut surface of the rind will be seen to have a greenish colour, which extends also for a short distance into the cellular tissue. This green colour is owing to the dispersion of a minute quantity of the same matter which gives the colour to the leaves. It is to this substance that those organs

owe the property of separating carbonic acid into its two elements, and of eliminating the oxygen. The name of chlorophille has been given to it; and according to Mulder, it consists of carbon 18, hydrogen 9, oxygen 8, and nitrogen 1, in atoms.

A *vertical* section of a sugar-cane similarly examined, demonstrates a like organisation to the one just described. It also permits us to obtain a more distinct notion of the mode of arrangement of the different parts than we could otherwise have. When the plant has acquired a certain age its vessels are seen to be hidden by the thin surrounding envelope of woody fibre, incrusted with the before-mentioned "*matière*" of Payen, and it is with difficulty that we can procure a distinct view of them. But if we examine a similar section taken from a newly formed joint, into the tissues of which the "*matière incrustante*" has not been deposited, the vessels may be most distinctly seen by the aid of a tolerably good microscope. They are found running together in bundles of two, three, or four, and preserving a perfectly straight course parallel to the axis of the stem. They appear to be formed of a succession of rings, and resemble somewhat the windpipes of some animals; hence they have sometimes been denominated annulated vessels, and occasionally tracheæ. They pass directly along the joint from its lower to its upper extremity, without presenting any appearance of anastomosis, or any other communication with each other. At the knot or point of junction of two joints, however, there is a complete lacework of vascular tubes, some of which are curved or looped, others run horizontally towards

the periphery of the plant, apparently for the purpose of supplying nourishment to the young bud, while another set seems to communicate by a direct course with those of the joint above.



The adjoining cut presents the appearance presented by a longitudinal section of a newly formed joint when highly magnified, A representing the vessels, and B the cells.

Externally, the knot presents the appearance of a ring. This part marks the point at which the two joints unite: it is studded over with three or four rows of minute points, from one of which may be seen a bud in the act of development. They are the germinal spots of the plant, and find their analogy in what is called the eye of the potato.

In this neighbourhood, also, may frequently be discovered in greater or less profusion a powdery substance of a white or greyish colour. It is wax almost in a state of purity. Avequin has described it under the name of *cerosie;* and he mentions an important peculiarity in connexion with it, namely, that those canes which contain much sugar have little cerosie, while, conversely, those which have much cerosic have little sugar. That this wax is produced from the saccharine contents of the cane, by a transposition of their ultimate elements similar

to those already described, appears very probable; and the experiments of Gundlach tend to show that this change is not an uncommon one in nature. Bees that were fed exclusively upon a solution of sugar-candy in water produced wax. Moreover, Pelouze found that when a strong solution of sugar, mixed with a small quantity of caseine and a little chalk, was exposed for some time to a temperature of 80° or a little higher, a butyrate of lime was produced. The butyric is one of the fatty acids, and is consequently closely allied to wax in its composition. If such a change can be effected by man, it is not assuming too much to attribute a similar one to the operations of nature.

Although the anatomy of the stem of the sugar-cane is, as we have just seen, very simple, the physiology of the plant, that is a knowledge of the functions performed by each of its organs, and the mode by which these functions are effected, is a subject of considerable difficulty.

I have already stated, that water charged with gas and saline matters is absorbed by the spongioles at the extremities of the root, that it passes upwards through the stem by a combination of actions, as capillary attraction, endosmose, the influence of light and heat, assisted most probably by a vital influence little understood, until it reaches the leaves, where, under the influence of light, the chlorophille, or green colouring matter, absorbs carbonic acid from the atmosphere, evolving its oxygen, but fixing the carbon, which is immediately combined with the principles of water contained in

the crude sap. From this union a variety of proximate principles may be formed, in each of which the proportion of carbon is greater than the amount of oxygen necessary to convert it into carbonic acid, and in which the respective amounts of hydrogen and oxygen are in the proportion necessary to form water.

A great number of these substances have been enumerated, and the facilities with which they may be converted into each other either in the laboratory of the chemist, or in the still greater one of nature, has been described. But when our inquiries extend to that series of combinations which succeed each other, or exist simultaneously during the different periods of the life of a plant, from the moment of its first germinating until the time when, after fructification, its juices become almost exhausted; if we ask why, from the sap, sugar is deposited in one part of the plant, starch in another, or some proteine compound in a third, we must confess that our knowledge is exceedingly imperfect.

In the sugar-cane a train of actions similar to those described as occurring in other plants is observed to take place. Water, holding in solution carbonic acid, ammoniacal gases, and the saline matters required for the purposes to which they are destined, is absorbed by the roots; it is carried through the stem, and thence to the leaves by the annulated vessels. In this state it is known by the name of crude sap. Arrived at the leaves, the sap undergoes the changes just mentioned, and is in all

probability at once converted into cane sugar and water. Whether this really takes place, or whether, from the sap thus changed, the sugar is deposited in the cells of the plant by a process similar to that of secretion, we have no means of ascertaining with certainty. Of this we are, however, assured, that the vessels contain a fluid, consisting for the most part of crude and unassimilated substances, whilst in the cells is found a solution of sugar and water, in all probability free from any admixture of foreign matters.

During life there appears to be going on a constant exchange of principles between the contents of the cells and those of the vessels, by means of endosmose and exosmose. The cells absorb a portion of the water contained in the sap-vessels, by which the crystallisation of their saccharine contents is prevented; and they in return give to the sap a certain amount of their sugar, which increases its richness and nourishing properties.

The crude sap of the sugar-cane has never been analysed, but there is every reason to believe that it has a composition similar to that of other plants. According to Vauquelin, the sap of plants consists of extractive matter containing ammonia — *a compound of proteine;* a mucilaginous substance — *dextrine;* water and salts, which vary in each species. It has been stated that plants have, to a certain extent only, the power of selecting the substances with which their roots may be in contact, therefore the sap of a plant may contain at one time matters foreign to its natural constitution, which will not,

consequently, be generally found in another of the same species, but placed under other circumstances.

When any of the more perfectly soluble saline principles of a plant are found existing in the soil in an unusual quantity, we may expect to find them in the sap of vegetables cultivated on such a soil more than usually abundant. In these respects the sugar-cane does not differ from other vegetables; *foreign* matters are occasionally found in its sap, and still more frequently an excess of one or other of its saline constituents.

The contents of the cells are composed of much fewer materials than those of the vessels, consisting almost entirely of sugar and water. Whether any other substances are ever associated with these two is at present unknown; but if we can form an opinion from what takes place in a few other plants, which present close analogies in this respect to the sugar-cane, we must conclude that such is not the case. It is certain, also, that if any other substances be present their amount is exceedingly small.

We also have a right to conclude, from a similar method of reasoning, that the sugar contained within the cells of the sugar-cane performs the same office as the starch which is deposited in the roots and pith of plants of other species, namely, that of affording nourishment when the future exigencies of the plant may require it. When the sugar-cane is vegetating in all its luxuriousness, when joint upon joint is quickly being added; or when, from an excess of vigour, new buds are

sprouting from almost every joint, the contents of the cells consist of little more than water, the sugar being absorbed as quickly as it is deposited, to serve for the formation of the new tissues. When, on the other hand, time and a favourable season have conducted the plant to that stage of its existence which has been expressed by the term "maturity," when, for a time at least, its growth and development have ceased, in preparation for the performance of another function, the contents of the cells abound in their saccharine constituents. This condition of the sugar-cane is accompanied by a diminution of the quantity of the sap, and by a slowness in its rise; it is therefore the one best suited for the purposes of the manufacturer.

Cane-juice is the fluid obtained from the cane by a degree of pressure sufficient to lacerate and break to pieces its entire structure; it must therefore consist of a mixture of those two fluids, so different in their composition. How essential is it, therefore, to attend to these circumstances, and rather suit the crop time to the cane, than, as is too frequently the case at present, suit the cane to the crop time.

When a portion of sugar-cane, cut into thin slices and dried, is infused in cold alcohol, a peculiar substance remains in solution, which is obtained on evaporation. It is neither salt nor sweet to the taste, is uncrystallisable, and highly deliquescent. It is the "*matière liquescente*" of Hervey; its composition is unknown.

The saline matters found in the sugar-cane consist of acetates of lime and potash, the malates of

lime and potash? the chlorides of sodium and potassium, the sulphates of potash and lime, carbonate of lime, phosphate of lime, silica, and alumina. Their amount differs materially in the various parts of the plant. The leaves contain about 4 per 100, but the stem rarely more than from 0·4 to 0·6 per 100 of these inorganic substances.

Cane-juice. The term cane-juice is, as just stated, applied to the compound fluid derived from the cane by means of powerful pressure; it must, therefore, consist of many other substances besides sugar and water.

When recently expressed, it is opaque, frothy, and of a yellowish green, or sometimes greyish colour. It has an aromatic and sweet taste, and balsamic smell, and produces a slightly acid reaction on litmus paper. In the latter respect it offers considerable variations. Its specific gravity is said to vary from 1046 to 1110, from 7° to 15° Beaumé. These must, however, be considered as its extreme limits, which are very rarely observed. I have never seen it in any country of a density below 8·5° nor higher than 13°, the temperature being 80°. Its specific gravity usually fluctuates between 1070 and 1090, 10° and 13° Beaumé. The difference in density depends upon many causes, as the age of the cane, the climate, the soil, the season, the temperature of the atmosphere, &c.

Cane-juice consists of two parts, easily separated from each other by filtration, the one being a perfectly transparent fluid of a pale yellow colour, the other a dark green fecula, which remains upon the filter.

The latter, upon examination under the microscope, is seen to be formed of a green globular matter — chlorophille, portions of woody fibre, cellulose in the state of the broken up parietes of the cells, and a few shreds of coagulated fibrine. By the application of heat, and the addition of a small quantity of lime, these substances separate readily from the pure juice, and then constitute the *scum of the clarifiers*. This scum has been analysed by Avequin, who states that it consists of cerosie or wax 7·5, green matter 1·3, albumen and wood 3·4, biphosphate of lime 0·5, silica 2·1, and water.

The transparent liquid which remains when the above matters have been separated by filtration, consists of water, sugar, a small quantity of dextrine, varying, probably, from 1 to 4 parts in 1000 in ripe and healthy canes, soluble compounds of proteine, saline matters, and a colouring principle, distinct from the green matter mentioned above, being soluble in water.

On a small quantity of filtered cane-juice being placed under the receiver of an air-pump, and allowed to remain there until all evaporation had ceased, a thick yellow syrup was produced which obstinately refused to crystallise. But on the addition of a little alcohol, crystallisation took place on further evaporation.

This experiment was performed by Peligot; it has been repeated by me with a similar result.

When a portion of cane-juice, treated as before, that is, carefully filtered, is exposed in a glass vessel to the action of heat, it gradually loses its trans-

parency, becomes cloudy, and, on ebullition, thin, flocculent particles of albumen make their appearance, which, on removal of the liquid from the heat, fall to the bottom of the vessel in the form of a white precipitate. If the liquid be deprived of these flocculent particles, and then evaporated in vacuo at the ordinary temperature of the atmosphere, crystallisation will ensue, but not so completely as in the first experiment, a portion of it remaining in the state of thick syrup.

If a portion of filtered cane-juice be evaporated in a shallow vessel over a sand-bath, at a temperature varying from 180° to 200°, until it assumes the form of an inspissated syrup, partial but slow crystallisation will take place, the crystalline substance amounting to about one third of the syrup. On submitting the latter to a further evaporation in a similar manner, a very small amount of ill-defined crystals are produced.

These experiments teach us,—1. That cane-juice, without the addition of any foreign matter, when its water is evaporated at the ordinary temperature of the atmosphere, does not produce crystals of sugar. 2. That when it is exposed to a temperature a little below that of boiling water for the purpose of concentration, crystallisation of a part, but not of the whole, of its sugar takes place. 3. That on the addition of alcohol to the concentrated syrup, nearly the whole of it is converted into a solid crystalline mass on further evaporation.

We can explain the action of the heat and the alcohol in the above experiments only in two ways,

namely, that some chemical or chemico-electrical change has been effected on the sugar by the agency of those bodies; or that they have separated from the cane-juice a substance, owing to the presence of which the sugar did not evince its inherent crystallising property. The latter is the effect which has taken place. The substances contained in the cane-juice, besides the sugar and the water, are dextrine, the proteine compounds, and the salts. Of these, the only one which is equally acted upon by both alcohol and heat, is the proteine compound called vegetable albumen; the other organic substances are unaffected by the degree of heat employed in the experiments, but alcohol coagulates them all.

If cane-juice, merely filtered as above described, be allowed to remain at rest for a short time, it gradually becomes viscid and loses its transparency, a portion of its sugar having been converted into gum. The *viscous* fermentation has commenced. Should the temperature of the atmosphere not exceed 60° or 65°, as is the case in the Island of Madeira during the months of January or February, this change may go on until the whole of the sugar disappears.

When such is the case, the character of the cane-juice is entirely destroyed. It now presents the appearance of a viscid mucilaginous liquid, which possesses neither sweetness nor acidity, and which is incapable of undergoing the vinous fermentation.

Within the tropics this transformation is never complete; for, owing to the high temperature which

exists there, the viscous fermentation no sooner commences than it is followed by another which soon supersedes it, and which gradually converts the cane-juice into a liquid possessing a sour taste, and a smell somewhat approaching to bad vinegar. This is the lactic acid fermentation, the cause of so much mischief when it is allowed to take place.

The establishment of these two changes does not altogether prevent the partial development of a third, in countries where the causes which excite them are so redundant as they are in the West Indies. Indeed they are almost always accompanied in a slight degree by the vinous fermentation, the alcohol resulting from which is, as soon as formed, converted into vinegar. So that the *souring* of cane-juice is not always exclusively owing to the development of lactic acid, but is often dependent upon, to a greater or less degree, the formation of acetic acid also.

These changes are likewise accompanied by the formation of a small quantity of mannite.

When cane-juice, which has already been boiled and filtered, is submitted to the action of heat a second time, the flocculent particles which separated from the liquid during the first ebullition are not now observed, but in place of them a thin film is seen to form on the surface. A similar effect is produced in all liquids which contain caseine in solution. We have a familiar instance of this in boiling milk. It has been already stated that caseine is one of the proteine compounds found in cane-juice, in which it is held in solution by the presence

of a vegetable acid or acid salt, in the same way as it is found combined in the juice of the grape. As caseine cannot be separated from its solutions by heat alone, it is evident that when this agent is the only one to the action of which cane-juice has been submitted, the caseine must still remain dissolved in it in its original quantity. Syrups prepared from cane-juice thus treated undergo a partial crystallisation only, and are very much disposed to run into one or more of the varieties of fermentation just alluded to.

Boiled cane-juice likewise changes its chemical character with great rapidity, the three varieties of fermentation taking place in it simultaneously; but while the viscous and lactic acid fermentations predominated, as we have seen in the juice which has not been exposed to heat, in this the vinous fermentation is the one which is most active.

Caseine is, as has been already stated, insoluble in pure water; but when the water is acidulated by the addition of any of the vegetable acids or acid salts, or when it is rendered alkaline by a small quantity of potash, soda, or lime, it becomes in both cases a solvent of this principle. In the one it is separated from its solution by the addition of an acid, in the other by that of an alkali, *provided that neither be added in excess, otherwise it is first precipitated, and afterwards re-dissolved.* We can thus explain the necessity for the employment of lime in the defecation or clarification of cane-juice.

When defecated by the employment of lime, cane-juice may be made to crystallise almost en-

tirely on due evaporation at a high temperature. In this state also it runs rapidly into the vinous fermentation; and if the other two varieties are occasionally found to accompany the former, it is at the most to a very small extent.

The nature of the change produced in sugar by its conversion into the products of the vinous fermentation is explained as follows. When a small quantity of yeast has been introduced into a solution of cane-sugar, and again separated from it by means of filtration, the sugar will be found to have undergone a change, it will not crystallise on evaporation; and on analysis it is seen that it has been converted into glucose. If the yeast be allowed to remain a short time longer, the vinous fermentation will commence. This consists in the conversion of 1 atom of glucose into 2 atoms of alcohol, 4 atoms of carbonic acid, and 2 atoms of water, thus:—

		Carb.	Hyd.	Oxyg.
2 atoms of alcohol	=	8	12	4
4 atoms of carbonic acid	=	4	0	8
2 atoms of water	=	0	2	2
1 atom of glucose	=	12	14	14

It is frequently stated that an incipient degree of the vinous fermentation in syrup is rather beneficial than otherwise, by augmenting its granulating properties. This statement is probably true to a limited extent. We can understand that the formation of a small amount of alcohol may be accompanied by the coagulation and precipitation of a

small quantity of some foreign organic substance, the presence of which may enfeeble somewhat the crystallising power of the sugar. But these results would be more than compensated by the conversion of a part of the sugar into glucose, entailing a loss in the quantity of crystallised sugar that would be obtained.

The fact that fermentation may take place in cane-juice, after its defecation by lime and heat, would indicate that these two agents are insufficient to remove all the proteine compounds or ferments from it; and such is the case, for on the addition of a little diacetate of lead to cane-juice, which has been treated in that manner, a copious precipitate results, which, on the application of heat, emits ammonia.

The hydrates of metallic oxydes when in a nascent state, alumina, and infusion of galls, have a similar, although less powerful, action than the diacetate of lead.

The practical inference to be drawn from the foregoing remarks is the necessity of removing as completely as possible the azotised principles from the cane-juice, as by their prolonged contact the latter will inevitably undergo, during the different stages of its concentration, one or other of the catalytic changes above mentioned. But besides these effects, their presence, probably assisted by that of a small quantity of dextrine, tends powerfully to prevent the crystallisation of the syrup.

As there are certain substances which have the property of checking or preventing the various

fermentations to which cane-juice is liable, the occasional employment of them has been recommended. They consist, for the most part, of sulphurous acid united to a base, such as zinc or lime for instance. In a well managed boiling-house they will never be required, and it would be needless to say, that in sugar making, as in other arts, that which is not required should not be employed.

The *saline matters* found in cane-juice consist of those which are peculiar to the plant, and which are more or less soluble in water; they are the chlorides of sodium and potassium, sulphates of potash and lime, bisilicate of potash, alumina, a trace of iron, and a little biphosphate of lime. Besides these there are also one or two organic acids combined with one or more of the above bases; but their nature has not as yet been very clearly made out.

The aggregate amount of these substances, as might be supposed, varies considerably. It usually, however, constitutes from 2 to 4 parts in 1000 of cane-juice; but sometimes it would appear to be greater. This variation in quantity is owing to the nature of the soil on which the cane is grown. The excess is caused either by the introduction of a foreign salt, or by the great preponderance of one of those which are essential to the composition of the plant.

Although the quantity of saline matters contained in cane-juice may at first appear to be small, we must remember, that as the concentration of this liquid goes forward, the ratio between them

and the other constituents becomes far less disproportionate. Let us suppose that the evaporation of cane-juice containing only 2 parts of these substances in 1000 be such as to produce a syrup equal to $\frac{1}{6}$ of its original weight, it is clear that the syrup must contain of them 1·2 per cent. I have already stated, on the authority of Peligot, who has given much attention to this subject, that one part of the chloride of sodium will combine with nearly six times its bulk of sugar, and form a deliquescent compound, which is capable of liquefying another portion of sugar equal to itself in *bulk*. It is, also, very probable that the other saline constituents may likewise form similar combinations. Their presence, therefore, must always be considered injurious.

We possess no means of getting rid of these matters when once present, we should, therefore, prevent their introduction into the cane by draining the soil. This induces me to mention a cause of injury both to the vegetation of the canes and to the cane-juice obtained from them, not unfrequent in some of the West India islands.

Many of those islands, as is well known, are of volcanic origin, and their soils, particularly in certain localities, contain in large quantities a compound of two atoms of sulphur and one of iron, known by the name of iron pyrites. When this substance is exposed to the air, it is slowly converted to sulphate of iron and sulphuric acid, which remain in solution in the undrained water, rendering it sour and very detrimental to the roots of the

canes. Again, when this sour liquid is in contact with vegetable matter, and when the air is excluded as it is when this liquid percolates through a deep stratum of alluvial soil, it parts with oxygen to the decaying vegetable matters, and is again converted into iron pyrites. From these soils, also, sulphuretted hydrogen gas is often emitted in considerable abundance, which, in addition to the evil effects that its presence produces on plants, renders such localities extremely insalubrious to man. By drainage and by a proper method of agricultural treatment both these evils may be remedied, and estates which are at present almost uninhabitable may be rendered comparatively salubrious, and their produce improved both in quantity and quality.

The relative amount in which the substances which have been described enter into the composition of cane-juice under ordinary circumstances may, from an average taken from numerous experiments made by different persons, be expressed as follows :—

Water - - - - -	81
Sugar - - - - -	18·20
Organic matter, precipitated by diacetate of lead - - - -	0·45
Saline matter - - - -	0·35
	100·

The accuracy of this formula is supported by a great uniformity in results, obtained under a va-

riety of circumstances, and, were it necessary, could be confirmed by my own observations; but it is obvious from what has been previously stated, that cane-juice must offer considerable modifications in this respect, arising from the age of the plant, from climate, from soil, &c.

Peligot remarks, "that when the amount of foreign matter, such as the organic azotised principles, salts, &c., contained in cane-juice in the proportions given above, be compared with that which exists in the juice of the beet-root, the former may be considered as a fluid of almost perfect purity, that it may be regarded, indeed, as a solution of sugar and water."

It is true that cane-juice contains both a larger quantity of sugar, and, also, a considerably less quantity of foreign matters than the juice of the beet-root, and is, therefore, less prone to undergo the changes which the presence of those bodies promotes under the same circumstances. But it must be remembered, that the cane-juice in the West Indies is, at the moment of its expression, submitted to the action of an atmosphere, the temperature of which is from 80° to 85°, while the temperature of the atmosphere in France, at the season when the beet-root is best fitted for the purpose of sugar-making, rarely exceeds, and is not often so high as 50°. This difference of atmospheric temperature in the two cases tends much to the equalisation of their respective chances of fermentation.

Many circumstances will disturb the amount of

each of the constituents of cane-juice. Probably in no two colonies is the cane-juice precisely alike in this respect. But there are causes common to all, and which being always in operation in a greater or less degree, prevent the cane-juice of one year resembling in all respects that of another, although both may be the produce of the same estate. The planter necessarily strives to cut his canes at the period of their greatest maturity; but a variety of circumstances often prevents the accomplishment of his wish. During the days of slavery the reaping of the crops always required a space of time equal to four months for its accomplishment, at present, from the want of labour experienced in all the colonies, this period is considerably extended. In so long a lapse of time many changes may take place in the weather, which set all his calculations at defiance; for instance, renewed vegetation of the canes may commence, and then the character of their juice will be materially changed.

There are certain lands on which the canes never appear to ripen, they remain large, green, and watery; and except after a long continuance of dry weather they are little disposed to arrow. Canes of this kind are invariably found growing in soils abounding in saline matters, which act as a powerful stimulus to the *growth* of the plant, but which, in an almost equal degree, tend to prevent the deposition of sugar in its cells. Such soils are either those in which drainage is urgently required, or they are virgin lands recently brought into cultivation, and rendered preternaturally saline by the

burning of the vegetation which had previously sprung up from them. The juice obtained from canes that have been cultivated under these circumstances is the cause of great embarrassment to the sugar-boiler. In the first place, it often requires an unusally large quantity of lime for its perfect defecation. It is dark in colour, and its ebullition is difficult and irregular. On the continued application of heat it becomes viscid, its colour becomes deeper, and on further evaporation of its water it is very liable to burn.

The inspissated syrup obtained from it granulates imperfectly, and the sugar is dark in colour, soft and pasty. The molasses are too abundant, nevertheless they leave the sugar so slowly, that the drainage seems interminable.

On the other hand, should an alternation of sunshine and rain, which for the space of five or six months has induced a luxuriant vegetation in the plants and rattoons, be followed by a long continued drought, their growth will be prematurely checked, and they will often, under these circumstances, show a disposition to arrow. Should they now be cut, the juice will probably be found of a good quality, and easily made into sugar, the only attendant evil being its deficiency in quantity, owing to the small size which the canes have obtained. In such cases it might be thought advisable to cut the canes rather than to permit them to remain on the soil, with a risk of the cessation of vegetation. Such a course is often impracticable, for the estate is not yet prepared for it; even if it were, the planter

would not be justified in running so great a risk of a change in the weather at a season when long experience has taught him to expect it, and thus to jeopardise the whole of his year's labour; for with a return of rain vegetation would immediately commence, and then to the evil of having canes of unusual shortness would be added that of a juice poor in saccharine matter.

Should the drought commence a short time only before the season for commencing crop, that is, when the canes have attained their ordinary growth, the effect is an eminently beneficial one, for it consists of an inspissation of the saccharine contents of the cells by the exhalation and evaporation of their water, and it is at the same time accompanied by a diminution in the quantity of that fluid which has been described above as the sap. Cane-juice under such circumstances has a considerable density, and is often of great purity, so that, during and after its concentration, the sugar, to use a common expression, makes itself.

But if the drought, at whatever age of the cane it may have commenced, should continue beyond the time necessary to produce the effects above mentioned, the leaves of the plant turn yellow, the stem becomes red, and has a scorched appearance, and not unfrequently splits, or becomes hollow from a contraction of its cellular structure. The canes then are said to be *burnt*. The juice thence obtained is greatly deficient in quantity, and its quality is considerably altered. In extreme cases it is strongly acid; in this respect it varies much,

but it always requires a large quantity of lime for its neutralisation, while the addition of this substance to it is destructive in its effects. On the application of heat it becomes rapidly darker in colour, it boils unequally and lazily, is very apt to burn, and the syrup refuses to crystallise. The reader is now, I trust, able to understand the nature of the change that has resulted in these cases. In consequence of injury that the structure of the stem has suffered, the liquid contents of the different organs have been mingled, the azotised matters have acted as fermentative agents, and the sugar in whole or in part has been converted into gum, glucose, and lactic acid, the one or the other of them predominating in different cases.

A similar result, but arising from another cause, is of common occurrence in Louisiana. In that country the frost not unfrequently sets in before the canes are ready to be cut. The frost causes an expansion of the fluids, and a rupture of the organs which contain them. An intermixture of the saccharine and nitrogenised principles consequently ensues. Should the frost continue, no evil results are observed, for at such a temperature catalyssis is prevented; but should a thaw succeed the cane-juice becomes viscid and mucilaginous, the syrups resulting from it will not crystallise, and the only use to which they can be applied is that of distillation.

The effects produced on the cane-juice by the borer, by rats, and by all mechanical injuries, are explained on similar principles.

The Methods employed to ascertain the Quantity of Sugar contained in Saccharine Liquids.

The only variety of sugar ever found in healthy cane-juice is that to which in consequence of its being entirely crystallisable that term has been prefixed. We must now inquire into the means usually resorted to, to ascertain its amount in any liquid in which it may be contained.

The first to be mentioned, from its being the one most generally adopted, consists in ascertaining its specific gravity as compared with that of some other with which we may be familiar. Water being the one usually fixed upon for the purpose, we arbitrarily attach to it the specific gravity of 1000.

It has been shown, that the specific gravity of anhydrous sugar is, compared with that of water, as 1600 is to 1000. But as, in the state in which it exists as a vegetable principle, it is found combined with 5·3 per cent. of basic water, and also, as saccharine solutions always occupy a larger space than that of its two constituents when separate, in consequence of the expansion of the sugar in these cases, and which varies from $\frac{1}{15}$ to $\frac{1}{40}$ of its original bulk, according to its purity and crystalline structure, it follows that the real density of the refined sugar of commerce must be below that which these figures indicate, being about 1500; according to Biot, 1509.

As the amount of the other constituents of *cane-juice* is relatively small, its density is a test of the

quantity of sugar which it contains, sufficiently accurate for all practical purposes.

To ascertain the density of a fluid we must provide ourselves with a pair of scales of good workmanship, and which are carefully adjusted, a set of accurate weights and a glass bottle of such a capacity, that when filled so as to correspond to a mark or ring scratched upon its neck, it will contain exactly 1000 grains of distilled water at 60° temperature. The bottle, accurately poised by a weight in the opposite scale, is to be filled to the mark with the liquid, which is then to be carefully weighed; the weight is the specific gravity.

Although this is the most accurate method of arriving at the density of a liquid, it is too tedious to be used in the arts, and for all practical purposes the hydrometer may be safely substituted for it. This instrument is, I presume, too well known to require explanation; but as a few of my readers may not recognise it by that name, I may remind them that it is the one usually employed to ascertain the strength of rum or any other spirit. Two scales have been attached to it, in the one the specific gravity of distilled water being reckoned at 1000, the degrees rise above or fall below that number. The figure which is on a level with the surface of the liquid in which the instrument is immersed indicates the specific gravity. The other scale is the one generally in use in sugar manufactories and refineries in Europe; and an hydrometer so adjusted is commonly called Beaumé's saccharometer. On this scale water is marked as 0, or

zero, and each of its degrees comprises seven or eight of those on the former; the results obtained by it are consequently not so accurate. They are, however, sufficiently so for ordinary purposes; and in one respect this scale possesses great advantages, for owing to a variety of causes, which have been partly explained, the relative proportions of sugar and water in different solutions observe a tolerably close connexion with the numbers marked upon it, for each degree corresponds with about ·019 part of sugar in the solution, so that by multiplying the one into the other, the quantity of sugar is pretty accurately arrived at. For example, let us suppose that the density of the liquid examined is shown by the saccharometer to be 20°, then $20 \times \cdot 019 = \cdot 38$, which indicates the number of parts of sugar contained in 100 parts of liquid. The real amount ascertained by direct experiment is 37, but the two are wonderfully close.

When the density of the liquid is below 20° — ·018 is a better number to use as a multiplier: thus, if cane-juice have a density equal to 11° — $11 \times \cdot 018 = \cdot 198$ or $19\frac{8}{10}$ is the per centage of sugar which it contains. In a solution of sugar and water of this density, the amount of the former, ascertained by direct experiment, is 20 per cent.

The table at the end of the volume has been constructed from experiments made by dissolving pure sugar in distilled water at a temperature of 65°. An allowance should be made for the expansion of the liquid under the greater heat of the tropics, to adapt it for use in those countries; but for practical

purposes this may be omitted without entailing any very material error.

When saccharine solutions contain any other foreign matter, it is evident the quantity of sugar cannot be arrived at by the same method. In such cases chemists frequently cause the fluid to undergo the vinous fermentation, and then determine accurately the quantities of alcohol and carbonic acid which are produced; but this operation presents too many difficulties to be undertaken by those who are not practically versed in chemical manipulations.

Some years ago the celebrated M. Biot discovered that solutions of sugar, examined by means of polarised light, gave different results, according to the quantity of this substance contained in the solution, and also according to the variety of sugar experimented upon. I know not how I shall be able to render what I wish to say upon this subject, intelligible to those who are unacquainted with the phenomena presented by light when it is polarised. The attempt, however, must be made, for the subject is one of considerable interest to the sugar manufacturer, as most unexpected results have been obtained through its means, and we have every reason to expect still further discoveries by its more extended application; moreover, it affords a method of great simplicity, and one which can be easily employed for ascertaining both the amount of sugar contained in the solution and also its variety.

I am not aware that this method of examining sugar has ever been practised by the refiners or

molasses' boilers of England, but on the continent its employment has been extensive. To the colonial sugar maker it would be in the highest degree useful, as it would enable him to detect the catalytic changes so often mentioned at the moment they commence, and thus enable him to check them, or still better, to prevent their occurrence, by the exercise of due precaution.

If we take a piece of glass, one of the surfaces of which has been previously blackened by means of smoke or soot, and lay it on a table with its blackened surface downward, and then place near it a candle in such a position that the light may fall upon it at an angle of 56° 45′, the light thus reflected will be found to possess properties which it had not before. If the image of the candle on the glass be viewed through what is called a Nicholl's prism, that is a rhombic prism of calcareous spar, two images will be observed, each of which will present a different colour; if we now rotate the prism, the images will likewise turn the one round the other until they arrive in that position in which the one shall be placed directly over the other, when both will present the colour of the light from the candle. If we continue the rotation, not only are their colours found to change, but at length one of the images disappears altogether, at a certain determined position of the prism.

If a tube constructed of any appropriate substance be filled with a saccharine solution, and closed at both extremities by means of plates of glass, in such a manner that the fluid may be re-

tained within it, and then be interposed between the image and the prism, we shall observe two images in the position in which we before saw but one; and on further rotation we shall obtain a new position, in which the double image will appear. The arc described by the rotation of the prism determines the amount of action of the substance interposed. Instruments constructed upon these principles can be obtained from any of the philosophical instrument makers. A scale is attached to them, adjusted to measure in degrees the rotating powers of saccharine liquids.

The rotating power of water being 0, if any power be observed it must depend upon some substance contained in it; and in pure syrups this must, of course, be sugar. The amount of the power is in direct ratio with the quantity of sugar; in other words, with the density of the syrup and the length of the tube.

The value of this instrument does not consist merely in showing the *quantity* of sugar contained in a pure syrup, for that could be ascertained by finding out the density of the syrup, but it enables us likewise to discover whether its density be owing to the quantity of sugar contained in it, or to some other substance which possesses a different kind of rotation. The results produced when a solution of cane sugar is thus examined are seen to be effected by a rotation of the prism from left to right and from above downwards; but if a solution of glucose or sugar of fruits be substituted for the above, the effects will be produced by a rotation of the prism

in the opposite direction, that is from the right towards the left.

These effects, however, are not peculiar to the two varieties of sugar mentioned above, but they are also observed in many other substances; for instance, the effects observed on the examination of a solution of dextrine are in many respects similar to those described as occurring when a solution of cane sugar is submitted to the same mode of investigation, so that were these two bodies to be so mixed together as to form a solution of a density of 20°, we should be led into a serious error were we to trust to the results produced by the polariscope as indicative of the amount of sugar that it contains.

When we apply this method of investigation to cane-juice, we should remember that there is always present in this fluid a small quantity of dextrine. But when the canes are healthy and mature, the quantity is so minute that its effects are insignificant, and the results produced may be attributed exclusively to the cane sugar. The amount of the latter substance may thus be very accurately ascertained.

If a syrup obtained from healthy cane-juice, and which is of such a density as to indicate that the amount of cane sugar which it contains is equal to 60 parts in 100, be, on examination by polarised light, found to possess a rotating power equivalent to that which would be produced by half of that quantity only, we should conclude that its powers of rotation have been disturbed by an admixture of some other

substance which is possessed of powers of rotation in an opposite direction, and, in all probability, that this substance is glucose, which has been formed during the process of concentration, or previously.

Evaporation is very frequently employed as a means of ascertaining the amount of cane sugar contained in any solution. When the solution consists of pure sugar and water only, and when the evaporation of the latter is performed at the ordinary temperature of the atmosphere, this method may fulfil its purpose tolerably well. But in this case it is unnecessary, as the density of the liquid is a correct indication of what we wish to ascertain. When the evaporation is performed at a high temperature, the result obtained cannot be depended upon, from the risk of converting a part of the cane sugar into glucose.

The method usually resorted to by chemists, for ascertaining the amount of sugar contained in a given solution, is either the following, or one closely resembling it. Presuming that cane-juice is the saccharine fluid to be examined, a weighed quantity of it is filtered and a portion of very strong alcohol equal to half its bulk is added to it; a flocculent precipitate immediately takes place, which is removed by a renewed filtration. The liquid is then placed under the receiver of an air-pump, into which is, at the same time, introduced a vessel containing a quantity of perfectly caustic lime. On the air being exhausted, the water, in consequence of the affinity which its vapour and the lime have for each other, is evaporated, while the alcohol remains.

In the course of ten days or a fortnight, the alcohol becomes too strong to retain the sugar in solution, and this substance is, consequently, precipitated. The precipitate is then to be washed in strong alcohol, and, having been carefully dried, it may be weighed and its amount ascertained.

An equally accurate result may be obtained by boiling and filtering the cane-juice, and then evaporating it in a shallow vessel over a water-bath, until it has acquired the state of a very thick syrup. A small quantity of spirits of wine is added, and the two liquids are blended together. The mixture is then treated under the air-pump in the way just described. This experiment does not occupy the length of time required by the former one, and it is equally effective.

Or the cane-juice, having been boiled and filtered, may be concentrated in a shallow vessel over a sand bath, at a temperature not exceeding 150° or 160°, until it becomes almost dry. It may then be dissolved in boiling alcohol, and, after filtration, the solution is decantered into a bottle, which must be corked and laid aside until the crystals of the sugar are deposited. Although the results obtained by this mode of proceeding are said to be tolerably accurate, and although it is more generally practicable from its not requiring the employment of an air-pump, I greatly prefer either of the two former when they can be performed.

PART II.

CHAPTER I.

MEANS RESORTED TO TO EXTRACT THE JUICE FROM THE CANE. — SUGAR MILL. — QUANTITY OF JUICE OBTAINED UNCERTAIN. — HYDRAULIC PRESS. — SLICING AND DRYING OF THE CANES. — MICHIEL'S PROCESS. — RESULTS OBTAINED. BY MILL INCREASED BY CARE AND ATTENTION. — FIVE-ROLLER MILLS. — FOUR-ROLLER MILLS. — WANT OF ECONOMY IN THE EMPLOYMENT OF MEGASS AS FUEL. — MOTIVE POWERS APPLIED TO SUGAR MILLS.

THE period of the year has arrived when the canes are to be cut, and their saccharine fluid expressed, that it may be converted into sugar. The preceding efforts of the planter are now to be tested, they are about to assume that form by which their value is to be estimated, and on the quantity and quality of which his profit or loss for the year will depend.

That it is the interest of the planter to obtain the largest possible amount of sugar from the canes appears to be so obvious, that we can scarcely suppose that a doubt could be expressed respecting it.

But does the planter of the present day so consider it? Does he believe that the object for which the canes have been cultivated at so enormous an expense, is that of obtaining sugar from them exclusively?—or has he overcome so many difficulties

in bringing them to maturity, that he may employ them for some other and ulterior purpose? These questions will be answered presently.

I must, however, at once declare that his sole consideration, after having obtained the canes in the most perfect condition that circumstances have permitted, ought to be the means to which he should resort for extracting their saccharine constituents in the greatest abundance, and in the greatest purity.

The fluid contents of a cane form 90 per cent. in weight of the entire structure of the stem; they consist of water, holding in solution a large quantity of crystallisable sugar, and a small amount of other substances, the presence of which would prove highly injurious if not removed shortly after the vitality of the plant has ceased. The remaining ten parts constitute the woody tissues of this portion of the plant.

It has likewise been shown that it is highly probable, if not certain, that during the life of the cane the various substances which enter into the composition of its juice are never found mingled together, but that sugar and water alone form the contents of the cells, whilst the others are found in solution in the sap vessels exclusively.

The anatomy of the sugar-cane teaches us, that to obtain these two fluids separately is altogether impracticable; nevertheless, we may inquire whether the *whole of the sugar* can or cannot be obtained in a state, more or less free from an admixture with the other substances, by means which are applicable

to the manufactory, as we have seen that it can be effected in the laboratory of the chemist.

The means at present resorted to, or which have been proposed for adoption, to extract the saccharine matter from the cane, are the following:—

1*st. The Sugar Mill.* This is the mode universally employed in all the colonies for extracting the saccharine constituents of the cane. The construction of the mill is too well known to require description. It may be sufficient to say that it consists essentially of three rollers, which are placed sometimes in a horizontal, and sometimes in a vertical direction.

The canes are submitted to the action of these rollers; and, in consequence of the great pressure and squeezing which they undergo, the whole of their tissues are completely broken up and lacerated. The degree of pressure is always so managed, however, that each cane shall, as far as possible, be drawn from between the rollers, preserving its entire length, so that it may the better serve the purpose for which it is ultimately destined, namely, that of fuel, by the exclusive means of which the sugar of the following year is to be manufactured.

Cane-juice, thus obtained, must necessarily be a very heterogeneous fluid, comprising not merely a varying amount of all the soluble substances which enter into the formation of the plant, but also of much solid and insoluble matter likewise. The latter consists, for the most part, of cellulose and woody fibre, of earthy particles which have adhered to the cane, of green colouring matter, &c., and which are easily separable by filtration.

We possess no information by which we can ascertain the precise amount of the fluid thus obtained from 100 lbs. of canes in the British sugar-growing colonies. I have questioned many planters upon the subject, but always without success; and my own observations have been too limited in their extent to deserve much weight as an authority.

Fortunately, we have other sources of information which, by enabling us to learn the results obtained in foreign but neighbouring colonies, furnish us with data for arriving at a knowledge of those obtained in our own.

Three or four years ago M. Duprez, pharmacien in the French marine, was sent by his government on a special mission to Guadaloupe, for the purpose of making a series of experiments on the composition of the sugar-cane. This gentleman, attaching a just importance to the quantity of cane-juice which is ordinarily obtained from the canes, details a number of experiments which he performed on this point on various estates throughout the island. The weight of canes in each trial varied from 200 lbs. to 12,000 lbs., and the average amount of juice furnished by 100 lbs., crushed in the different mills, was as follows: —

1. By mills having horizontal rollers; the motive power not stated - - - 61·2 lbs.
2. By mills; motive power, steam - - 60·9
3. By mills; motive powers, wind and steam - 59·3
4. By mills having vertical rollers - - 59·2
5. By mills; motive power, cattle - - 58·5
6. By mills; motive power, wind - - 56·4

He further states, that although the quantity of cane-juice varied from 68·5 to 54 per cent., the average of his experiments was 56 per cent. only.

M. Avequin gives 50 per cent. as a general average of the juice expressed from canes in Louisiana, while M. Senez states that he only obtained 36 per cent. of cane-juice, by means of a mill worked by steam. M. Paul Daubrée, in a pamphlet, the translation of which by Mr. Thompson of Jamaica, is, I believe, generally known among planters, considers 50 per cent. as a full average expressed by the mills throughout the Island of Martinique. The lowest amount that my own observation in the West Indies permits me to give, is 47 per cent., and the highest, 61 per cent.; but, as I have just mentioned, it has been too limited to be offered as an authority. In the Island of Madeira I obtained at two different times by the same mill, and from canes of similar character and quality, 47·5 and 70·2 per cent. of juice. The mill was a small one, made at Aberdeen about two years previously, on the ordinary principle, with horizontal rollers, and the motive power was cattle. During the experiment which furnished the last and largest result, the rollers were braced more than usually tight, and the number of canes introduced at a time were five or six, being the utmost that the strength of the cattle would admit of. The canes were squeezed once only; indeed, the megass was too much lacerated to admit of its being passed between the rollers a second time with advantage.

There is a considerable difference, as we may

perceive, in the results given above, but this difference does not excite so much surprise as the comparatively small proportions of cane-juice, which appear to be obtained as a general average in those countries in which this matter has been investigated.

How far these results correspond with those which would be obtained by a general and strict inquiry being established throughout the British colonies, it would be idle even to surmise; but there is every reason to believe, that the comparison would prove an unfavourable one to the latter. Many reasons lead me so to believe:—1. Because we can scarcely expect to find superiority, or even equality, where no attempts have been made to obtain it. 2. That when we are ignorant that a deficiency exists, little pains will be bestowed to correct it. 3. When, from the force of circumstances, more attention is paid to the obtaining of an abundant supply of megass, to serve as fuel for the concentration of the cane-juice of the following year, than I, at least, have ever seen evinced for obtaining a full and adequate supply of juice for the present.

Let it not be supposed from the above remarks, that I consider that the French planter possesses a more extended knowledge of his art, greater acquirements, or more industry than his English *confrère*. I should be sadly unjust towards my countrymen by such an insinuation. I have had opportunities of appreciating the qualities of both, and unhesitatingly acknowledge, as a general rule,

that both as agriculturists and sugar-boilers the latter are superior. But this admission does not invalidate what I have just stated; for, attention having been drawn to this subject in the French colonies in a very remarkable degree, it has received far more consideration there than it has in our own possessions.

The due and efficient expression of the juice from the cane is a subject of the very highest importance, for it is evident that upon this cause alone may depend the fortune or the ruin of a proprietor of a sugar plantation.

2. *The hydraulic press* has been proposed as a substitute for the mill, and as a better means of expressing the cane-juice. It has been introduced into Jamaica and St. Vincents, but with what success I am unacquainted. I know not whether it has ever been submitted to a fair trial, and the results obtained by it compared with those obtained by the mill.

Unfortunately, there is no organised system as yet established among the colonies, by which the knowledge and experience of one may be diffused among the many. From the want of the means of reciprocal communication, repeated and well ascertained failures of a scheme, which have caused its rejection in one colony, do not prevent frequent and renewed trials of it in others. Or, if it has proved successful, ignorance of its success, aided most probably by a scepticism which has been rendered obstinate from witnessing repeated failures, causes a long period to elapse before its reception becomes

general. Thus it may have been with the hydraulic press. May not its more general employment have aborted for some similar reason ?

3. It was proposed a few years ago to cut the canes into thin slices, which were to be dried, either in the sun or by means of artificial heat, and then forwarded to Europe for the purposes of manufacture. This scheme was tried in Guadaloupe, and, as might be imagined, failed. Decomposition of the canes commenced on board ship, and on arrival in France the whole of their sugar was destroyed. Moreover, if they had arrived in a perfectly sound state, the trouble and expense attending the operation of slicing and drying, coupled with the additional freight, render it questionable whether the scheme would have been remunerative.

4. A few months ago a patent was taken out for the French and British colonies by M. Michiel, for extracting the sugar from the cane by an entirely new process. It consists in cutting the canes into extremely thin slices, and then submitting them to the action of a mixture of lime and water, which, it is presumed, will coagulate and render insoluble the whole of their nitrogenised constituents; thus permitting the extraction of the whole of the sugar with the soluble salts by means of water.

Were this process as practicable as its admirers seem to think, it ought, unquestionably, to be universally adopted; for I believe that were it skilfully carried out, almost the whole of the saccharine matter in the canes would to a certainty be ex-

tracted. It remains, however, to be seen whether it is really so practicable, or whether its application will be sufficiently cheap. I much fear that the circular knives, by which the canes are to be sliced, if we may judge from what occurs in the slicing of the beet-root, will be subject to continual derangement, and their edges blunted by the silicious coating of the cane. It may be doubted whether the operation will prove a sufficiently speedy one to admit of its adoption on large estates. The amount of evaporation demanded would also be great. This, it is true, may be obviated by placing the canes, thus sliced, in a succession of boxes having perforated bottoms, and placed one over the other in such a manner that boiling water poured into the upper one will gradually percolate through each of the subjacent ones, and thus, by robbing the canes successively of the greater portion of their sugar, the saccharine liquid will become gradually more inspissated as it descends, until, when it comes away from the lowest box, it will have assumed the state of a syrup of considerable density.

I offer the above remarks, frankly, because I think that this scheme presents much that is admirable; nevertheless, like many others, it requires the touchstone of experience.

After all, it must be admitted that at the present time, the only means which have been sufficiently tested to give us the confidence we have a right to demand, for obtaining the saccharine fluid from the cane, is the mill. We must, therefore, attempt to the utmost of our power to correct, at least in

some measure, its present imperfections, or rather the imperfect results obtained by it.

I have shown that from a more tight bracing of the mill, the quantity of cane-juice obtained from 100 lbs. of canes may be augmented from 48 lbs. to 70 lbs.; but it is evident that to effect this increase a corresponding augmentation of the motive power will be required.

Our present inquiry is confined to the means to be adopted to render the mills already erected more effective than they are generally found to be. The improvements in their construction, and the application of the most advantageous motive powers will be considered hereafter.

To render a mill as efficient as possible, the following rules should be attended to: —

1. The rollers should be made to approximate as closely as the work which they have to perform will admit of. In mills, in which the rollers observe a vertical direction, the space between the first and second should scarcely, if at all, exceed $\frac{1}{4}$ of an inch, whilst a distance of $\frac{1}{6}$ of an inch is the most that should be allowed between the second and third. When they are placed horizontally, the upper one ought to observe a space of $\frac{1}{5}$ to $\frac{1}{4}$ of an inch from the two lower. These distances can never, perhaps, be accurately given in every case, but the requisite degree of bracing should always be strictly attended to. 2. The velocity of the rollers should be rendered as uniform as possible, not by diminishing the amount of the motive power, but by a carefully regulated supply of canes.

3. The canes when thrown upon the feeding board should be upon the same plane, and never suffered to cross each other, otherwise the motion of the rollers will be checked, and the canes will be submitted to unequal pressure. 4. The megass should invariably be repassed between the rollers, so as to extract, as much possible, the juice which still remains in it.

When the canes are rich, and their juice of considerable density, the megass should be sprinkled with a little water, or, where it is practicable, exposed to the action of steam before it is submitted to the pressure; but when the canes are large, green, and watery, this may be dispensed with.

By following the foregoing rules, the quantity of cane-juice may be increased, at least, 20 per cent., that is, a mill which ordinarily gives 50 lbs. of juice for every 100 lbs. of canes which are crushed by it, may by a little attention be made to increase the quantity to 60 lbs. at least, and the one which now produces 60 lbs. may be made to yield 70 lbs. from a like quantity.

This amelioration may be obtained without any additional outlay of money; a little watchfulness on the part of the planter, to see that his orders are carried out, being all that is required for its accomplishment.

There are, unfortunately, many mills, which, either from age, the want of solidity originally, or from a construction altogether imperfect, produce even an inferior result to those given above. A comparative amelioration will follow the application

of these rules in all cases; but the only real amelioration which can be effected in the cases alluded to, is the removal of the old mill and the erection of a new one. The present, it is true, are not the times when sugar properties in the West Indies permit an indiscriminate outlay of capital for the purchase of new machinery. But it must be remembered, that the difference between 45 or 50 lbs. and 70 lbs. of juice, extracted from equal quantities of canes, indicates a corresponding difference in the amount of the crop; while the annual expense attending the cultivation of the estate, would be in both cases the same. If the erection of another mill be decided upon, we may inquire into the principles that should guide us in its selection.

One evil attending the mill composed of three horizontal rollers, is the re-absorption of a part of the cane-juice by the squeezed, but spongy megass. Another and much greater one, is the loss of power caused by the oblique direction of the crushing force and the inordinate amount of friction.

Mills have been within the last few years manufactured with five rollers, which are placed with regard to each other, in the same manner as are the three rollers in the usual horizontal mills — that is, two are placed above and three below. Mills thus constructed have been successfully used in Cuba, Bourbon, and the Mauritius, 70 per cent. of juice having been obtained by them at one operation, without much greater laceration of the megass than is usually produced by the three-roller mill. But, as might be foreseen, a great

objection has been raised against them, owing to the very considerable increase of motive power which they require.

Latterly, sugar mills have been constructed with four rollers, which are placed two below, and the other two above and immediately over the former. These mills have been greatly extolled, producing, as it is said, from 70 to 75 lbs. of juice from 100 lbs. of canes, with a motive power little, if any, greater than that which is required by an ordinary three-roller mill of equal size. I have not seen mills of this construction in operation, but I believe that the advantages, which they are said to possess, have not been exaggerated.

That, by any mechanical means, the whole of the juice will ever be extracted from the cane, cannot be expected; indeed, from obvious physical causes, this result would be impossible; but it is certain that the quantity at present obtained, 50 lbs., may very readily be increased to 70 or 75 lbs. from 100 lbs. of canes.

It is evident, that in recommending the effective squeezing of the canes, the preservation of the megass has been regarded as a very secondary consideration.

No doubt it would be exceedingly agreeable, were we able to extract the entire amount of juice from the canes, and yet find in the remaining 10 per cent. of woody fibre, &c., a sufficiency of fuel to evaporate an equal amount of cane-juice during the ensuing crop. Unfortunately, we cannot have our cake and eat it too. The question to be decided

is very simple, namely, whether all our labours have been expended in raising canes for fuel, or for the manufacture of sugar.

The absolute quantity of wood contained in the stem of a sugar-cane is 10 per cent. of its weight. The only other constituent which, when the cane is carefully exsiccated, may likewise serve as fuel, is the sugar, and this may be considered as amounting to seventeen parts per cent. The quantity of water will then be about seventy-two parts in one hundred. These proportions are subject to variations from many causes; but they are sufficiently stable to illustrate what I wish to point out, namely, that the amount of combustible substances contained in the cane is to the water as 27 to 72.

The extent of evaporation that can be effected by the combustion of sugar has not, I believe, been ascertained in this part of the world; it is only in the colonies that the extensive use of this substance as an article of fuel is ever heard of. Let us, however, suppose that the mixture of sugar and wood, such as exists in a carefully dried cane, equals in this respect coal, and that when it is employed in the unskilful and wasteful manner at present practised with the megass, it is capable of evaporating five times its weight of water. It will follow that the fuel obtained from 100 lbs. of dried canes, is equal to effect the evaporation of 135 lbs. of water, or in other words, that it will be able to inspissate the whole of the cane-juice contained in 200 lbs. of canes, to the state of a strongly granulated syrup.

Fifty pounds of megass (if carefully dried and preserved with the greatest care) obtained by the expression of an equal weight of juice from 100 lbs. of canes, would, by a similar calculation, contain ten pounds of wood and $\frac{4}{9}$ of 17 lbs. of sugar = to about $17\frac{1}{2}$ lbs. of fuel, capable of evaporating $87\frac{1}{2}$ lbs. of water, or, of reducing to perfect dryness, the whole of the juice contained in 121 lbs. of canes.

Unfortunately, it is found in practice impossible to dry the megass in such a manner as to preserve within it the quantity of combustible materials given above. For whether it be stacked at once, or be previously exposed for some hours to the rays of the sun, fermentation of the juice retained in it commences, and the sugar is converted into incombustible bodies, as gum, lactic acid, &c., or, into others, which are rapidly evolved, as carbonic acid and alcohol; so that when the time arrives when its use as fuel is required, little more remains available for the purpose than the woody fibre, that is to say, that instead of obtaining $17\frac{1}{2}$ of fuel from canes which have given 50 parts in 100 of juice, 10 parts only are actually serviceable; and the amount of evaporation which could be effected by this quantity, would be equal to 50 lbs. of water only.

The planter would appear to be in a great measure aware of this fact, by offering as a reason for the imperfect pressure to which he submits the canes, the fear of having a larger evaporation to effect than his fuel is capable of accomplishing. When he states, however, that by imperfect pressure

he is thereby obtaining a proportionately increased supply of fuel for the following year, he is manifestly in error, for the only constituent of the cane on which he can rely for that purpose, is the woody fibre, which will be equally abundant to whatever extent the pressure may have been carried.

To exemplify the loss which a sugar plantation annually sustains from an adherence to this most shamefully extravagant system, I will suppose, that by increased pressure the amount of cane-juice obtained is augmented merely from 50 lbs. to 60 lbs. in every 100 lbs. of canes. It is clear that the amount of sugar, molasses, and rum, must be increased in the same proportion, and, therefore, an estate, which otherwise would give 200 tons as its annual product of sugar, would, from this cause alone, afford 240 tons.

Let us also suppose, that there being no other available fuel at hand in place of the megass, coals have to be imported from England, at an expense of 1*l.* per ton, and that 240 tons would be required to evaporate the requisite quantity of cane-juice to make the same number of tons of sugar; the price of the coals would represent the expense attending the augmentation of the produce. The sugar would be worth at least 20*l.* per ton, consequently, the clear gain would be 800*l.* less 240*l.*, or 560*l.*

The profit, however, would not be confined to the mere increase of forty tons of sugar; the megass, after due fermentation, would produce an amount of farm-yard manure, which, when thrown

upon the land, would augment the quantity of canes for the ensuing crop, at least, 20 per cent., and, in the greater number of colonies, very much more. In Barbadoes, for instance, there are many estates that after a good supply of manure, readily yield, in favourable seasons, three tons of sugar per acre, which, without that assistance, would not yield one.

But, admitting that a planter may not choose to employ his megass in that manner, it is still available for the purpose of fuel, for its woody tissues remain in all their integrity; and, probably, by its employment, the quantity of coals required would be reduced to less than half the quantity given above.

I cannot, however, leave this subject without again entreating every proprietor of sugar estates in the West Indies, to give it his most serious consideration. If, as I believe, the average quantity of juice expressed from the canes in those colonies does not exceed 50 per cent., and, if by a moderate share of attention, it may be increased to 70 per cent., by means already possessed by the great majority of estates, it is evident that the augmentation of the produce that would follow the adoption of a careful and economical system of expression, would be equal to 40 per cent., and that the only additional outlay which would accompany it would be the cost of the material employed for fuel. If we take 30 tons as the weight of plant canes grown on one acre of land, and if we suppose, that by a judicious pressure, 70 per cent. of juice has been

obtained from them = 21 tons, we shall possess nine tons of megass available as a manure. We will also admit, that three tons of coals would be required to concentrate this quantity of cane-juice to a crystallisable syrup, and that their cost would be 3*l.* This must be placed against the nine tons of manure, the value of which would be, at least, 4*l.* 10*s.*, or 10*s.* per ton; consequently, the value of the megass employed as manure, would be 50 per cent. greater than it is when used as a material for fuel; and the increased saving to the estate would observe the same proportion.

Motive Powers applied to Sugar-mills.

The motive powers attached to the sugar-mills in all the colonies, consist of cattle, wind, water, and steam. Whatever be the power, it is essential that it should be sufficient for the purposes which it has to perform; and that it should be at all times available. When these requisites have been obtained, we may then study, what is generally so much talked about in the colonies, economy, a term, however, which is often most egregiously misunderstood.

Cattle-mills are still very generally seen in many of the colonies. The animals usually employed are mules. From their great cost, from the number required to perform the work, from the mortality to which they are subject, and from the additional

labour which their care, food, &c., entails, this kind of power is very expensive. The only advantage that I have ever heard attributed to it, is the manure which its employment furnishes. Manure must, indeed, be much wanted, and its value must be great under such circumstances; for the droppings of animals so lean and ill fed, as those poor creatures too often are, are almost worthless for such a purpose, being scarcely better than the herbs that they have fed upon.

Wind is frequently employed as a motive power, and, in Barbadoes, it may be said to be almost the only one. It offers, at least at first sight, economy as a recommendation, which, without doubt, is a very considerable one. The trade-wind, which sweeps across the tropical portions of the Atlantic Ocean, particularly during the period of year when the sugar crop is going forward, constitutes a force sufficiently powerful for the ordinary wants of the mill. But even there it does not altogether lose the character of fickleness so commonly attributed to winds in general; so that it not unfrequently happens, that the crop is retarded until the juice of the canes has much deteriorated, by the setting in of the rains, probably at a period unusually early, from the want of a sufficient amount of motive power. I think, that where this power is used, it ought always to be accompanied by a small high-pressure steam-engine, as an auxiliary when circumstances may require it.

Water, where it is sufficiently abundant, and where the supply can be always depended upon, is,

unquestionably, the power best suited to the circumstances in which the West Indies are placed. It is as economical as wind, it is more powerful as generally applied; it is very manageable, and its force is easily regulated; and, at the same time, it is unaccompanied with the same uncertainty. Unfortunately, few estates are so situated as to admit of the application of this power.

Steam is a power that is universally applicable, and its employment, consequently, is becoming daily more general. Its advantages are indisputable; but it would be impossible to discuss in this place a subject so extensive. The steam-engine best suited for the purpose we are inquiring into, is that which is denominated the *high-pressure engine.* As at present constructed, this kind of engine may be used without fear of accident, its cost is small; it is easily managed and kept in repair, and its economy both in fuel and water is considerable.

CHAP. II.

DEFECATION OF CANE-JUICE AS AT PRESENT PRACTISED. — ITS UTILITY. — ITS IMPERFECTIONS. — PRINCIPLES WHICH OUGHT TO GUIDE US IN ITS PERFORMANCE. — IMPROVED METHODS. — FILTRATION.

THE juice having been expressed from the canes, its defecation, or as it is usually called, clarification, ought immediately to be proceeded with.

In many colonies this operation is dispensed with. When it is performed the process is as follows: —

For the most part the cane-juice, as it comes from the mill, is received into a cistern capable of holding 500 or 600 gallons or more, in which it is permitted to remain until the clarifiers, or one of them, is ready to admit it. These cisterns, or cold receivers, as they are called, are made of copper occasionally, but, generally, they are merely wooden boxes, lined with sheet lead. Their use is very properly becoming less frequent daily.

Where the cold receiver is not in use, the cane-juice passes from the mill directly into one of the clarifiers, which are shallow copper pans of a circular form, almost flat, or rather arched slightly upwards at bottom, and capable of holding from 250 to 500 gallons each. Each is hung over a separate fireplace, which is supplied with a damper to regulate the combustion of the fuel, or for checking it altogether when required.

When the clarifier is nearly filled heat is applied, and on the cane-juice attaining a temperature which varies according to the fancy of the person who has charge of the operation, but which is usually about 140°, a portion of lime is added, either in its caustic state, or in that of a hydrate, or, as it is called, *slaked*. Usually the lime is slaked by means of water, and it is then made to form a milky or creamy looking fluid; but occasionally this effect is produced by the addition of clarified cane-juice, or of syrup taken from one of the coppers. The latter plan has its admirers; for the lime, when thus treated, having entered into combination with a due proportion of sugar, its combination with the sugar of the cane-juice, it is thought, is less likely to take place.

In which way soever employed, the quantity requisite to perform the desired effect is a point on which few sugar-boilers agree; they all admit, however, that it varies according to the quality of the cane-juice.

To ascertain with greater accuracy the amount of lime required, it is customary in many boiling-houses to fill three or four wine-glasses with cane-juice drawn from the clarifiers, and to drop into each successively increased quantities of lime-water; the one which produces the most favourable result being taken as the indication of the quantity demanded.

On the addition of the lime, the cane-juice is freely stirred, so that the two bodies may be intimately blended together. The heat is cautiously

increased until it approaches the boiling point, and until a thick scum forms upon the surface, which cracks and separates into two or three pieces, allowing the clear liquor to be seen between them.

The fire is then extinguished, and the cane-juice is suffered to remain undisturbed until the remaining feculencies have subsided. When this is supposed to have taken place, the cock of the clarifier is turned, and the clarified juice passes immediately into the grand copper.

Cane-juice defecated in this manner is generally transparent, of a yellow colour, occasionally approaching to orange; it may be alkaline or neutral, or slightly acid, according to circumstances. On attentive examination, minute flocculent particles may always be discovered in it, either by the naked eye, or with the assistance of a common lens.

One or two planters of my acquaintance are in the habit of submitting the cane-juice to a double clarification; the first by means of heat alone, the second with heat and lime combined.

The above is the plan usually pursued in performing one of the most important operations in the whole process of sugar-making; although in many respects the object to be attained by it is but imperfectly accomplished, nevertheless, very considerable benefit is at all times derived from it.

By defecation, our purpose is to remove as much as possible from the cane-juice all those substances which are likely to injure the quality of the sugar by their mechanical mixture with it; or those, the presence of which would, if long continued, inevit-

ably produce some chemical change in its saccharine principle, and thereby either diminish the quantity of sugar which ought to be obtained, injure its quality, or produce both these results.

Those substances are, as before stated:—1st. Insoluble impurities, consisting of small particles of earthy matter, bruised pieces of cane, chlorophylle, &c. 2d. The proteine compounds, albumen, and caseine. 3d. Soluble colouring matter. 4th. Salts. We possess no means of getting rid of the last mentioned, as I have before had occasion to state.

The separation of the first, or insoluble impurities, can be effected by means purely mechanical. In the West Indies these matters are permitted to run into the clarifiers, as we know, and are separated only subsequently to the application of heat. But this plan always entails a loss of cane-juice, which is retained in a considerable quantity in the bulky scum at the top and the thick sediment at the bottom. This loss may be prevented, and a better defecation obtained by submitting the cane-juice to a coarse straining, rather than a filtration, previously to its going into the clarifier.

Filtration of the cane-juice, antecedent to its passage into the clarifier, has been repeatedly practised, and discontinued, in consequence of its either being too tedious an operation, or from the difficulties which have attended it. The object of filtration at this early stage, it should be remembered, is merely to separate the coarser insoluble particles suspended in the cane-juice. It must be performed so rapidly that the means employed shall

offer no impediment to the free transmission of the passage of the liquid, or add to the risk of decomposition ensuing. For this purpose a large double-bottomed sieve should be suspended over each clarifier, the meshes of which should be formed of metal wire $\frac{1}{12}$ of an inch apart in the upper one, and $\frac{1}{30}$ of an inch in the one below. When the sieve is foul, after each filtration, the upper bottom must be removed, and the adhering impurities washed out.

The removal of the proteine compounds, albumen, and caseine, and the soluble colouring matter, cannot be effected so easily; for this purpose we must call in the assistance of chemistry. The only chemical agents at present employed are heat and lime.

The first coagulates, and renders insoluble the vegetable albumen which at the same time envelopes and entangles a large quantity of the flocculent particles suspended in the liquid, and thus assists considerably their separation, in the same way as the white of egg, or the serum of the blood, when added to liquids that it is wished to clarify. Heat alone, however, is insufficient to produce those effects upon cane-juice which are understood by the term defecation. Syrups obtained from cane-juice thus treated would show little disposition to granulate, while they would have a strong tendency to decompose. Experience has shown this to be the case; therefore, from time immemorial, the application of heat has been assisted by the addition of lime, or an alkali obtained by the incineration of some favourite vegetables. Both soda

and potash, either in their caustic states, or as carbonates, defecate cane-juice equally as well as lime; but the great injury that their presence would inflict upon the sugar and molasses, renders them inadmissible for this purpose.

The action produced by caustic or recently slaked lime on cane-juice, is a very complex one; and I believe we are at present far from thoroughly comprehending it. It merits attentive consideration.

When a drop or two of the milk of lime be suffered to fall into a tumbler of cane-juice, the colour of the latter is immediately changed from a greyish green to a bright yellow, on the spot where the lime has fallen. This change of colour is accompanied by the separation of the liquid into two parts, the one being a solid heavy precipitate, formed by the collecting together of the insoluble impurities; the other, being the cane-juice rendered tolerably clear by the separation of those substances.

Lime saturates any free acid it may meet with in the cane-juice; it sets free a small quantity of potash; it forms an insoluble compound with a portion of the caseine, which is either precipitated, or which rises to the surface in the scum; it combines with three times its weight of sugar — the substance produced being very sparingly soluble in cold, and still less so in hot water; it deepens the colour of the juice.

When the cane-juice contains a small quantity of lactic and acetic acids, an event which occurs more frequently now than formerly, owing to the want of a sufficiency of labour to hasten the stages of the

manufacture, the lime combines with those acids, and forms uncrystallisable salts, which preserve a portion of the sugar with which they may be in contact in a fluid state.

Should a small quantity of glucose be present in the syrup, which is always the case when concentration has been conducted as it now is in the colonies, the lime, probably assisted by a small quantity of potash which has been set free, speedily converts it into glucic acid; and the glucates, when formed by the prolonged action of the heat, are as quickly converted into melasinates of the same bases, and the whole syrup is thus rendered of a dark brown or black colour.

Cane-juice, defecated as judiciously as possible by means of lime and the application of heat, throws down a further precipitate on the addition of a little diacetate of lead.

It might be supposed, that as lime and heat alone are insufficient to produce the entire separation of all injurious substances from the cane-juice, and, as the employment of the former is far from being entirely innocuous, that its use ought to be dispensed with, and that some other substance ought to be substituted for it.

We have seen, that many substances are capable of throwing down caseine from its solution in cane-juice, more or less completely; but the action of some of them is less complete than that of lime; and others are inadmissible, either in consequence of the ulterior injurious effects which would be produced on the sugar, or from their poisonous quali-

ties. We are therefore compelled to continue the employment of lime, either alone or, still better, associated with other substances which promote its powers; and, consequently, enable us to use it in quantities so small, as to remedy many of the evils which result from it as at present administered.

1. *Defecation by means of lime, and subsequent filtration.* The first thing to be attended to, is the quality and method of preparing the lime. This substance ought to be as pure and free from admixture with silicious or other foreign bodies as possible. It should be carefully burnt, and immediately slaked with boiling water, which should be added in such a quantity as to form a mixture of the consistence of cream, and the whole should be strained through a fine wire sieve.

The cane-juice, previously strained as before recommended, having been received into the clarifier, heat is to be applied to it as quickly as possible. In the meantime, its acid reaction should be tested by means of litmus paper, so that we may form an idea of the quantity of lime which will be required. Usually, the acid reaction is slight, but decided, that is the litmus paper is changed by it from a blue to a reddish purple or purplish red; but cane-juice presents great variations in this respect, and with the amount of variation will depend that of the lime to be added.

The temperature of the liquor in the clarifier having risen to about 130°, a measure of the milk of lime, containing from four to six ounces of pure burnt lime, is to be added, and the whole intimately

blended together by means of an oar for a minute. The liquor must be again tested, and, if necessary, an additional quantity of lime must be given to it, until it presents a perfectly neutral reaction; that is, until it neither changes the blue colour of the paper to a red, nor that into blue which has been previously made red by the vapour of vinegar. The heat is to be continued until perfect ebullition has been established for two or three minutes. The cock of the clarifier is then to be turned, and the liquor passed directly into the filters.

Each clarifier is supposed to contain 300 gallons. The filters which may be employed, are either the common bag filters or the charcoal filters, both of which will be explained presently. The latter, however, is an operation uncalled for in this stage of the manufacture of sugar from the sugar-cane, if the defecation has been carefully attended to.

From the filters the liquor should pass directly into the coppers, whenever this can be accomplished. Unfortunately, as the generality of boiling-houses are arranged, this is rarely practicable, in which case it must run into a cistern constructed for the purpose, and be pumped from thence into the pans.

When carefully performed, and the quantity of lime accurately given, this method is a very good one, and answers very well if the cane-juice be good, healthy, and freshly expressed.

When the quantity of lime has not been quite sufficient, so that the liquor has a slightly acid reaction, the colour of the sugar will be light, but the grain small; on the other hand, if the liquor be

slightly alkaline, the grain of the sugar will, *cæteris paribus*, be bolder, firmer, and larger, but the colour will be darker.

Whatever be the kind of vessel employed to perform the above, or any of the succeeding modes of defecation, it is essential that it shall be constructed of copper. The ordinary clarifying pans of the West Indies are all formed of this metal; but some of those which have been latterly introduced, and which have been constructed on the same principles as the blowing up cisterns used by refiners, have been made of, or lined internally, with iron; and I need not say, that they are, in consequence, unfitted for the performance of many of the most successful methods of defecation about to be described.

2d. *Defecation by nutgalls.* To two ounces of nutgalls, finely bruised, add half a gallon of boiling water; infuse for twelve hours, and strain; neutralise, by means of cream of lime, a clarifier of cane-juice containing 400 gallons, and when the temperature is about 150° to 160°, add the infusion of galls; mingle the whole together by means of a ladle or an oar, boil for three or four minutes, and filter through bag filters.

This method may be followed with advantage when the cane-juice is viscid, without increased acidity.

3d. *Defecation with sulphate of zinc.* To a clarifier containing 300 gallons of cane-juice, previously deprived of its insoluble impurities by straining, add, as soon as possible, twelve ounces

of sulphate of zinc; apply heat, and when the temperature has risen to 150°, add as much milk of lime as will render the liquid neutral, or, in the slightest degree, alkaline; boil for two or three minutes, and filter through bag filters.

There are few substances which defecate better than sulphate of zinc, employed in this manner. But it must be remembered, that this substance is poisonous, and, whenever used, it is absolutely necessary to filter the liquor through bag filters, which retain the sulphate of lime and insoluble oxide of zinc, in combination with the organic matters that have been acted upon; while the defecated liquor passes through free from any deleterious admixture.

4th. *Defecation by means of alum.* Dissolve four pounds of common alum in a sufficient quantity of pure water, and when the cane-juice in the clarifier (350 gallons) is just beginning to get warm, pour it in and mix well with an oar or ladle. The cane-juice will now have a strong acid reaction, and the heat must be quickened, as much as possible, to 140°, so that neutralisation may be effected by the addition of milk of lime, added in repeated doses, until the litmus paper is no longer altered. Boil and filter as before.

Common alum is a combination of sulphuric acid, alumina, and potash. In the above operation, the lime has set free the alumina, which immediately combines with the colouring matter; and the free lime and sulphate of lime, produced by the decomposition which has taken place, precipitate

almost entirely the other organic substances of the cane-juice, leaving the sugar unaltered. We could, therefore, desire no better means of accomplishing our object, were it not that the sulphate of potash is retained in solution in the cane-juice, and its operation on the syrup and sugar, ultimately obtained, would be injurious.

5. *Defecation by means of the sulphate of alumina.* This substance is employed in the way just described for alum. It does not contain potash, but is composed of alumina and sulphuric acid only. The proportions required are about one pound to every 100 gallons of juice; but twice, or even thrice that quantity, may be given with advantage. We must be careful, however, to neutralise the liquor, thus treated, as quickly as possible with milk of lime, otherwise some risk would be incurred of converting a portion of the sugar into glucose. Every pound of the sulphate of alumina will require about seven or eight ounces of caustic lime to effect its decomposition; but a slightly additional quantity may be given in all cases, beyond what is merely necessary, although the liquor may thereby be rendered slightly alkaline.

I can conceive no better method of defecating cane-juice than this. The liquor as it comes from the filter is almost colourless; and all the after processes to which it is submitted, are extremely satisfactory. I have produced sugar from cane-juice thus acted upon, equal in colour to the finest clayed Havannah, and possessing a sharp and sparkling grain.

Unluckily, the sulphate of alumina is not an article of commerce in this country, owing to there being no demand for it. It can, however, be obtained from France, where it is used in the manufacture of beet-root sugar. We possess by the decomposition produced, three defecating substances of considerable power; namely, the alumina, the sulphate of lime, and the free lime which has been added in excess.

The application of this plan is attended with little expense, and no trouble; and the results obtained are, as I have just stated, such as to recommend it for general adoption.

6. *Defecation with the sulphates of alumina and zinc.* A combination of these two substances may *occasionally* be employed, I think, with some benefit. A few experiments induce me to advise a trial of the plan, if merely to ascertain in what respect the results obtained differ from those of the last. The proportions used by me have been, one pound of the sulphate of alumina, and two ounces of the sulphate of zinc, to 100 gallons of juice. The way of proceeding is exactly as above, and the lime must be added as indicated by litmus paper.

7. *Defecation by means of alumina and sulphate of lime.* This method is one which has been pursued with some advantage by refiners, both in this country and in France. Two pounds of common alum are to be dissolved in about two gallons of water, either in a wooden or earthenware vessel; purified chalk, which is a carbonate of lime, is slowly to be added, and the two intimately mixed

together. When all effervescence is over, and does not recommence on the addition of a little more chalk, the decomposition is complete. The mixture is allowed to stand until the alumina and sulphate of lime have subsided. The supernatant water holding the sulphate of potash in solution, is poured off, and other water added; and this must be repeated until all taste of the sulphate of potash has disappeared. The mixture is then to be thrown into the clarifier, and intimately mixed with the cane-juice when lukewarm; the above quantity being added to every 100 gallons. Lime must be used to neutralise the cane-juice when the temperature has reached 150°. The whole must be boiled for a few minutes and filtered as before.

8. *Defecation by sulphuric acid.* About two fluid ounces of sulphuric acid, diluted in thirty times its bulk of water, is thrown into 300 gallons of cane-juice, at a temperature of 120°, and the whole well stirred together. In about three or four minutes, four ounces of lime, prepared as directed, are to be added, and the stirring continued until the temperature reaches 170°. More lime is then to be added until the liquid is perfectly neutral. It must boil for a few moments, then be filtered.

At the first sight this would appear to be a most unskilful and injurious way of treating cane-juice. The action of the sulphuric acid, if long continued, would convert the whole of the sugar into glucose; and it is not improbable that this effect is produced to a very small extent, even in the short time that

the two are in contact. The injury, however, is less than, under the circumstances, might be supposed.

But it is not on healthy cane-juice that this method of defecation should be employed; for the results obtained by the others are, in such cases, very much superior, whilst they are unaccompanied by any mischievous consequences. There are, however, certain states, in which cane-juice is occasionally found eminently benefited by this mode of treatment.

Almost all viscid cane-juice is so, but that which is obtained from one of the conditions of the cane, described, usually, as being "burnt," is the one to which it is most applicable.

9. *Defecation by diacetate of lead.* When seven parts of finely powdered litharge, six parts of sugar of lead, and thirty parts of water, are digested together at a moderate temperature, the liquid which is found at the top consists of this salt in solution in the water. It constitutes the *liquor plumbi subacetatis* of the pharmacopœia, and is often considered as a tribasic salt.

If to 300 gallons of cane-juice, accurately neutralised with lime or chalk, five ounces by weight of this liquid, diluted in a quart of distilled water, be added, and the whole be carefully stirred and heated, the most complete separation of all the organic matters, sugar alone excepted, is immediately effected.

A patent was taken out a few years ago by some parties in this country, for defecating cane-juice

and other saccharine liquids, by this means. It was therein proposed to precipitate any excess of the diacetate of lead which might remain in solution with the diphosphate of lime.

This process requires a double clarification; the acetate of lead should be added in one vessel, then the cane-juice, having been deprived of all the insoluble coagula which had resulted from the action of this substance, must be passed into a second; and therein, when mixed with a certain quantity of the diphosphate of lime, it must be boiled for a few minutes, and again filtered.

On the addition of the diphosphate of lime, it is presumed that the soluble diacetate of lead will be converted into the insoluble phosphate of lead, and that the acetic acid will form, with the lime, an acetate of lime.

That this double decomposition would take place under ordinary circumstances, must be admitted; but that it will *always* do so, at least, perfectly, when sugar is present in the solution, may be doubted.

I have defecated cane-juice repeatedly with the diacetate of lead, employing, however, generally the sulphate of alumina as the decomposing agent. In every instance the test of sulphuretted hydrogen was applied to the filtered liquor; and it not unfrequently happened, that, in spite of all the care bestowed, a quantity of lead was detected in it.

For this reason, from the additional time and labour required for the double clarification, and from the amount of acetic acid set free, which,

whether in that state or when combined with a base, would prove injurious to the sugar, I conceive that this process would be inapplicable to the manufacture of sugar in the colonies.

Indeed, it has been used there, and the consequences which ensued to a great number of persons who made use of the sugar, are now a matter of history. The effects produced in the case alluded to, were, no doubt, much more severe than they would have been, had the cane-juice or syrup been properly treated; so that a portion of the lead having been rendered insoluble, had been separated by means of filtration. The fact of their having been produced, however, indicates the impropriety of admitting the employment of the salts of lead in any of the processes, either of the manufacture or the refining of sugar. Its presence is easily detected, and, if no other evil consequence ensued, its discovery would cause all sugars, imported from the estate where it had been employed, to be regarded with suspicion, if not altogether unsaleable, for a long time afterwards.

10. The bark of the wild elm, *theobroma guazuma*, has been used in Martinique and Guadaloupe for defecating, or rather for clarifying cane-juice, with considerable success it is said. I have never seen this substance employed, and therefore am ignorant of its value as a *defecating* agent.

I have now mentioned all the methods of defecation, which I think may be employed with advantage in a colonial boiling-house. I have endeavoured to point out the importance of this operation, and

to show, that upon its being well or badly performed depends much of the success of all the subsequent processes.

That defecation may be effectual, a temperature sufficient to produce the ebullition of the cane-juice is necessary. As at present performed, the cane-juice is not allowed to boil; otherwise the separation of the flocculent coagula and other solid matters from the liquor in which they are suspended would be impracticable. The heat is raised to that point, merely, which is necessary to produce the cracking of the cane-juice; and this degree effects a partial separation only of the substances which are coagulated by heat.

Should the temperature exceed the above point, ebullition would ensue, and filtration is then required to separate the coagula. The advantages which filtration at this stage of the manufacture present may be stated as follows:—1st. The greater facility of managing the operation, as the cane-juice being allowed to boil, the attention at present required to the due regulation of the temperature may be dispensed with. 2d. Ebullition is essential to the complete coagulation of the albumen. 3d. Economy of time, as, after two or three minutes of smart boiling, the liquor is allowed to run into the filters at once. 4th. An increase in the quantity of liquor, as nearly the whole passes through the filters, the solid matters alone being retained. 5th. The complete separation of all solid matter, and the greater transparency of the defecated juice.

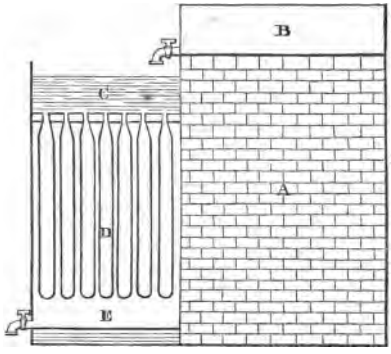
The necessity for the filtration of the cane-juice

being performed, either at an early or later stage of the manufacture, is so obvious and so universally admitted; and as it is an operation which can be performed in every boiling-house, as at present constructed, during some part of the process of sugar-making, it is surprising that it has not been universally adopted.

The filters in use in Europe to separate the mechanical impurities from syrups are known by the name of bag filters: they consist of a number of strong calico bags, about eighteen inches wide, and from three to five feet in length, each of which is introduced into another bag of the same length, but only six inches wide, and made of a strong and open canvass. Into the neck of each sack, thus arranged, is inserted a short metal tube, to which the sack is tied, and by which it is fixed to the bottom of a cistern adapted to receive the cane-juice as it comes from the clarifier. This vessel is placed over the case in which the filters are contained.

It is obvious, by such an arrangement, a large amount of filtering surface is obtained in a very small space. We are, therefore, supplied with a means of most perfect, and, at the same time, most rapid filtration. This apparatus can very easily be made in every colony. The case may be very conveniently constructed of wood, and at the bottom should be attached a cock, which either allows the liquor to escape into the coppers, when practicable, or, when that is not the case, into a receiver constructed for the purpose. The apparatus should

be placed under the cock of the clarifier, and, of course, the number of them must be equal to that of the clarifiers. Each should contain a set of twenty bags; and another set should be provided for use when the first are being cleaned. The accompanying sketch will enable us to form an idea of the construction of a set of bag filters, and their mode of application.



A. Wall of clarifier.
B. Clarifier, with cock.
C. Upper cistern of filters.
D. Filters enclosed in their case.
E. Lower cistern and discharging cock.

If the double sieve, formerly described, is not employed for straining the cane-juice previously to its admission into the clarifier, it ought now to be used and placed between the cock of the clarifier and the lower part of the upper cistern of the filters; otherwise the bags would be speedily choked, and the operation would consequently be retarded.

A very few dollars would be required to form the necessary number of filters if expended in the colony. If preferred, they may be obtained from any of the coppersmiths in the large towns of England and Scotland.

In the manufacture of beet-root sugar, the de-

fecated juice, instead of passing through bag filters, is made to percolate through beds of animal charcoal, which has already been nearly exhausted by the filtration of inspissated syrup. On an estate where animal charcoal is used for the filtration of the syrups, it may be advisable to wash out the adhering syrup with cane-juice instead of water, as it may be considered more economical. I doubt, however, whether this would be a very practicable operation on a large estate, and when time is so much an object.

The foregoing remarks are applicable to the clarifying vessels now in use in the colonies. These vessels, perhaps, might be made a little deeper with advantage.

Steam defecating vessels have been lately constructed. They consist of an iron chest lined with copper, in which is coiled a hollow pipe, made of the latter metal, having an area and length sufficient to supply the due amount of high pressure steam to effect a rapid ebullition of the cane-juice.

Were steam the heating medium in use in the other stages of the manufacture, no doubt it would be equally applicable to the one before us. But to use it in this part of the process where it is not required, and not in the others, would be a piece of folly, which, I trust, it is not necessary to point out.

CHAP. III.

EVAPORATION, OBJECT OF. — PRESENT METHOD. — OBJECTIONS TO IT. — IMPROVED METHODS OF. — BY NAKED FIRE. — BY STEAM.

HAVING separated as completely as possible from the cane-juice those substances which are liable to produce mischief, both by preventing the successful performance of the succeeding operations, and by the injurious effects which their presence produces on the sugar, we next proceed to evaporate a large proportion of its water, and reduce it to the state of a syrup.

At the present time the liquor, on leaving the clarifier, passes at once to the coppers, where renewed defecation, evaporation, and concentration of the syrup into sugar, are carried on simultaneously.

These coppers are segments of hollow spheres, they are five in number, are all arranged on the same plane, and are acted upon by one fire.

When this plan was originally introduced into the West Indies is unknown, but it appears to have been in use in India from the earliest period.

That three operations so very important as defecation, evaporation, and concentration, should be performed at the same time and in the same vessels, without serious injury arising in one or other of

the processes, a little reflection would show to be impossible, and experience has proved that it is so.

That this plan has been continued up to the present time is not the fault of the planter. Until recently the introduction of fine sugars into this country was virtually prohibited by the extraordinary differential duties attached to them. The planter, consequently, sought to obtain, by the cheapest means in his power, the largest possible quantity of an article best suited to give him a money return for his labours. Thus the sugar manufacture in the colonies was restricted to the obtaining from cane-juice a semi-crystallised concrete, which we recognise in Muscovado sugar.

Under such circumstances, it is not surprising to find old authors rapturously extolling a plan which, whatever might be its imperfections as a means of obtaining a thoroughly good product, allowed, as was then imagined, the planter to produce such a one at least as his position exclusively permitted, with economy, with little trouble, and without the exercise of much manufacturing skill.

A knowledge of what really occurs when cane-juice and syrups are evaporated and concentrated in this manner, might lead to a doubt whether economy either in time, labour, fuel, or money, is effected thereby; indeed it is now generally acknowledged, that not only is this plan unfitted for the manufacture of a superior quality of sugar, but that the objects which alone admitted of its defence are attained far less completely than its admirers imagined. For the form of the pans, their globular

bottoms, and the distances which exist between them, cause them to present a comparatively small effectively heating surface; whereas the mass of masonry, in the shape of copper walls, arches, &c., instead of being kept as cool as possible, offer even a larger amount of surface for the absorption of the caloric than the vessels which it is intended to heat.

That this system can be continued, except at a great sacrifice, cannot be disputed; we should therefore attempt by every means in our power to remedy its defects. The object that I have principally had in view throughout these pages has been to obtain improved results, by inculcating a knowledge of correct principles, rather than by the recommendation of new and expensive machinery. Pursuing the same design, we will now extend our inquiries as to the best way that amelioration of this part of the process can be attained at the smallest cost, and with the least disturbance of the present plant.

The manufacture of sugar comprises three operations, namely, defecation, evaporation, and concentration, which are so distinct from each other, both in the mode required to perform them, and the objects to be attained by them, that their separation is indispensable.

Evaporation has for its object the concentration of cane-juice to the consistency of a syrup of that degree of density best suited to the process which it has afterwards to undergo. Thus, if the syrup is to be filtered through animal charcoal previously

to its concentration into sugar, the density which is best suited for this purpose is 27° or 28° Beaumé; but if this operation is not to be performed, the evaporation may be prolonged until the syrup has acquired a density of 30° or 32°.

Evaporation of cane-juice is best performed by ebullition at the ordinary atmospheric pressure. That degree of heat, at this stage, during which the sugar is largely diluted, when judiciously applied, so that the syrup may not be exposed to it longer than is absolutely necessary, is always beneficial, and often essentially necessary; for, otherwise, a larger portion of the nitrogenised matters, which have not been entirely removed, would be retained, and the crystallisation of the sugar would be less complete.

The means required to effect these purposes, it is obvious, are of very great simplicity, and may be attained as follows: —

1st. By retaining the present plant, the teache being taken away, and the fire made under the second copper. In this case the four coppers constitute the evaporating apparatus, and are to be employed for that purpose exclusively. The cane-juice, after defecation, is passed into the one most distant from the fire, and successively into the others, where it is to be skimmed and ladled, as at present, until it shall have attained, on arrival at the last, the density required, when it must be skipped either into charcoal filters, into a cistern placed for its reception, or into the concentrating vessel, as will be described presently.

This arrangement would be a very great improvement upon the present plan, and it may be obtained without much alteration in the plant, or without any outlay of money beyond that which is now required for keeping the copper walls in order; nevertheless it is in many respects still very imperfect. 1st. It requires the use of megass as fuel, in consequence of the distance which the flame has to pass over. 2d. It requires a larger quantity of fuel than is necessary to produce the amount of evaporation demanded. And 3d. It requires the labour of four men to ladle the liquor from copper to copper.

These, I think, are reasons sufficiently satisfactory for advising the introduction of some other system, whereby those expenses would, in a great measure, be spared. I am, however, too well aware of the unhappy condition of the colonies to expect that, for the present at least, any improvement which requires even a small outlay of money to effect, will be generally adopted, if the same results, though at a greater cost, can be obtained by means which every estate now possesses.

2d. The next alteration in the plant which I propose, consists in substituting for the present coppers a large flat-bottomed vessel, made of cast-iron or copper, of an oblong shape, with the angles rounded off, to protect them from the action of the fire. It should be divided in the centre into two equal compartments, by a metal plate containing a valve, by means of which the liquor may be passed from one into the other when required.

It must be hung in such a manner, that the

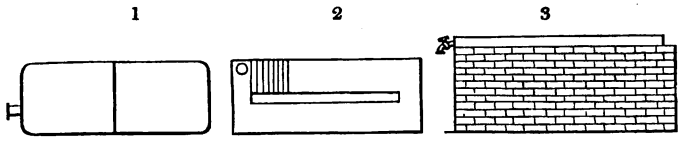
flame may come into contact with every part of the bottom, but be prevented from touching the sides.

The dimensions of the vessel will depend upon the work to be performed by it. On an estate having three clarifiers of 300 gallons, each of which can be filled by the mill, and the juice boiled and filtered in three quarters of an hour, the size required for the evaporating pan would be fourteen feet in length, seven feet in width, and eighteen inches in depth. Two such would be necessary.

When set, the pan should be surrounded by a sloping border of lead, in the same way as the present coppers, to admit of the rise of the liquor during ebullition. The separation between the compartments should be of the same elevation as the pan itself, so that the contents of one side may readily overflow into the other. The skimmings are to be taken away when necessary, but as no ladling is required, one man would be sufficient to perform all the duties required by it. A large cock should be attached to one extremity, by which the syrup may be drawn off when sufficiently concentrated.

The vessel should never be completely emptied, except at the close of the day. Generally, the quantity taken away each time will be equal to the contents of the clarifier, less the water lost by evaporation. To effect this when the juice is at 10° Beaumé, the rate of evaporation must be about 200 gallons, and the quantity of syrup ob-

tained in consequence, 100 gallons at 27° every three quarters of an hour.



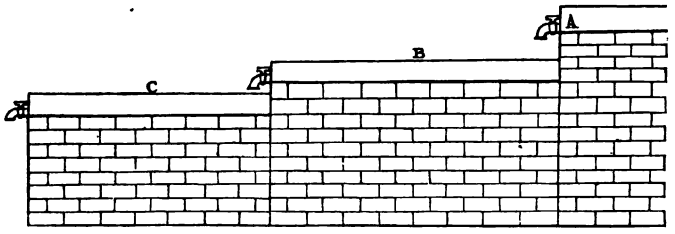
The above diagram will enable us to understand the pan more accurately than we could do, probably, by description only. 1. The outline of the pan. 2. The furnace on which it is hung. 3. The pan set in mason work.

3d. The evaporating vessels may be, if it should be thought preferable, arranged in another manner. Should this plan be adopted, the apparatus will consist of two flat-bottomed vessels, either of iron or copper, (in the latter case the bottom should be made to curve inwards). In shape they should approach a square, the angles being rounded off; and, instead of being hung upon the same plane, the upper edge of the lower one should be on the same elevation as the bottom of the one above. They should be so set, that the fire applied to the lower one will serve to heat the upper one also.

Their size should correspond with the work to be performed by them; and, supposing it to be the same as that given in the preceding plan, the upper vessel would require to be, at least, twelve feet long, eight feet wide, and eighteen inches deep; the lower one, nine feet long, eight feet wide, and eighteen inches deep.

The clarified cane-juice is to be received by the

upper vessel, and after undergoing a certain degree of evaporation, is to be transmitted to the lower one by means of a cock.



A. The cock admitting the defecated cane-juice into the upper evaporator, B. C. The lower evaporator, with its discharging cock.

Gay Lussac has remarked, that liquids are more easily converted into vapour, when in contact with uneven and angular surfaces, than when these are smooth and polished. Evaporation may be greatly promoted, also, by increasing the extent of the heating surface of the vessel in which it is carried on.

These facts have been taken advantage of in the arts, and evaporating vessels are now frequently made with their bottoms corrugated, which, by increasing the heating surface, augments likewise their evaporating powers. A patent was taken out two or three years ago for producing a similar effect, by extending from the outside of the bottoms of pans, a great number of metallic studs or projections about two and a-half or three inches long.

The evaporating properties of every vessel may be greatly increased by these contrivances. I, therefore, think that more attention should be bestowed upon

them by planters in general than what has hitherto been done.

It has been found that the material of which the evaporating vessel is composed, influences the temperature at which ebullition takes place. When a glass vessel is coated inside with a thin film of shellac, the temperature of water boiling within it has been observed at 220°, or even higher. This teaches us the necessity of keeping the bottoms of the evaporating vessels clean, and free from those deposits so frequently found adhering to the inside of the coppers.

Steam has within the last few years been extensively employed on the Continent as the heating medium for evaporating the defecated juice of the beet-root; indeed, it is now the one almost exclusively employed in those countries, in all the operations of this manufacture in which the action of heat is required.

The kinds of apparatus which have been constructed for the employment of steam, as the agent for procuring heat, have been so various as not even to admit of their enumeration. They may, however, be divided into those which consist of shallow vessels with double bottoms, into the space between which the steam is admitted, and into others which are deeper, and in which a copper steam pipe is introduced in the form of a coil or spiral.

The evaporation which takes place in these vessels is often extremely rapid, and there can be no doubt, that in other respects they present a

marked superiority over those vessels which are heated by means of the direct action of fire. These advantages, as far as regards the process of evaporation of cane-juice from its ordinary density, until it assumes the state of a syrup at 27° or 28° Beaumé, we must inquire into.

Whatever be the medium employed to produce evaporation by ebullition at the ordinary pressure of the atmosphere, it is evident, that the liquid acted upon, must in every case rise to the temperature necessary for the performance of this action. Steam offers no exception to the rule; but it enables us to effect ebullition in liquids with great rapidity, and, at the same time, with less liability to burning than can be performed over the naked fire; because it admits of the heating surface being increased to almost any extent, and of its being at the same time immersed in the fluid to be heated.

Steam is very manageable, and admits of the *amount* of caloric applied to the liquid being regulated at pleasure, so that in the case before us the heat may be instantly withdrawn, and the evaporating vessel be converted at once into a simple cistern, when we require to empty it of the syrup.

These advantages, offered by the use of steam, as a means of effecting the evaporation of cane-juice, are certainly very great; and, on a large estate, requiring a new plant for the boiling-house, its introduction would, no doubt, in many respects be very beneficial. But whether it can be introduced with real advantage into a boiling-house already erected, in which the plant is in perfect

order, and where the estate does not produce annually 400 tons of sugar, is less certain.

In the first place the removal of the present plant, and the substitution of another upon the above principle, would be attended with a very considerable outlay of capital; in the second, such a change is not absolutely demanded, for the results obtained in the processes of defecation and evaporation over the naked fire, may, with an ordinary degree of care and watchfulness, be equally satisfactory; and lastly, the only decided advantage possessed by this method, is the entire removal of the heat from the pan when required without the trouble and annoyance of damping or drawing the fire. A very great advantage certainly; but will it compensate the capital invested for its attainment?

Although the employment of steam possesses all the above advantages, it is far from being so economical a method of producing evaporation as the open fire. How well soever an apparatus on this principle may be constructed, the loss of caloric will be considerable, and the consumption of fuel will be proportionately great. This is a serious drawback to the recommendation of steam, for, coupled with the additional expense of the plant, it will go far to neutralise its advantages. On those estates, however, where the vacuum pan is used for concentrating the syrups, that is, where steam is already in use, its extension to the other processes of the manufacture might be effected at so small an increase of expense as to render it profitable.

Whatever be the means employed to evaporate

the defecated liquor, expedition is urgently demanded, for the shorter the time that it is subjected to the boiling temperature, the less will be the risk of any of the catalytic decompositions being induced.

Cleanliness in this, as in all the processes, should be strictly observed.

The scum, as it arises in thin insulated films, should be removed and thrown back into the clarifier, as the syrup which it retains is too pure to be converted with profit into rum.

CHAP. IV.

FILTRATION THROUGH ANIMAL CHARCOAL.

HAVING, by the foregoing operations, succeeded in obtaining a pure and well defecated syrup of the required density, the colonial sugar-maker has arrived at that stage of his operations which corresponds with the first steps taken by the refiner in Europe; and from this point these two branches of industry ought to be considered identical. The former, however, is in a position of much less difficulty and embarrassment than the latter, for he has the power of exercising a discretionary opinion as to the extent to which the succeeding operations may be carried on, or whether it be to his interest to adopt them or not. He has obtained, if his efforts have been successful, a bright transparent syrup of the colour of pale sherry, capable of granulating with facility on due concentration, and of forming a fine canary-coloured Muscovado sugar. It is simply a matter of economy, whether this is to be the object sought to be attained, or whether, by the application of additional care, pains, and labour, his profits may not be more than proportionately increased by the superiority of the result obtained.

In the first case, he will at once proceed to the operation shortly to be described, that of concentration; in the second, he will follow the example

of the refiner one step at least in his business, namely, in the filtration of the syrup through a bed of animal charcoal.

The application of the fact, that *vegetable* charcoal possesses the property of discharging colour from syrups, to the purposes of art, was one of the greatest modifications that had taken place in the refining of sugars up to the period of its introduction in 1805.

In the year 1811, it was discovered that *animal* charcoal possessed the same power in a considerably greater degree, while its employment was not attended with many serious evils, which were found to accompany that of the former.

M. Derosne was, I believe, the first who caused the introduction of animal charcoal into the refineries of France. Some short time afterwards it was introduced into those of this country.

The mode of employing this substance at first was as follows: — The Muscovado sugar was dissolved in boiling water, in such proportions as to form a solution of about 30° Beaumé; the animal charcoal, in the state of a very fine powder, was then added, and the whole was mixed together by means of an oar. A quantity of bullock's blood was afterwards thrown in, the stirring being continued. The mixture was allowed to boil for a second or two, and then filtered through a blanket and basket, until the introduction of the bag filters, when the latter were universally substituted for that rude and imperfect method.

Some years ago M. Dumont being struck with

the great augmentation of power which animal charcoal presents when employed as a filtering agent, and when syrups were allowed to percolate through layers or beds of it, after many efforts, succeeded in constructing filters on this principle, which have since been in general use, and which bear his name.

However employed, the action of animal charcoal upon impure syrup is in the highest degree extraordinary, and has never as yet been satisfactorily explained.

The object sought on the first introduction of this substance into the refineries in France was that of discharging colour merely; but on being used for this purpose in the factories of beet-root sugar, it was quickly perceived that it possessed other properties equally important, and not less beneficial. Syrups treated by it were rendered crystallisable, which before, from their viscid character, had no disposition to granulate. Others that were slightly acid became neutral; and those containing an excess of lime had this excess removed.

It was afterwards discovered that many of the bitter and aromatic principles of vegetables were destroyed, when infusions prepared from those substances were filtered through beds of animal charcoal. Latterly the experiments of Dr. Garrod have shown that animal charcoal possesses still more wonderful properties — that it is, in fact, an antidote to some of the most virulent poisons of the animal and vegetable kingdom, as prussic acid, strychnine, aconitine, &c. That gentleman has

shown that when solutions of any of the alcoloids are mixed with washed, or purified animal charcoal, in the proportions of half a grain of the former to half an ounce of the latter, the filtered liquid possesses no poisonous property whatever. Vegetable charcoal produced very little, and lampblack no effect whatever, in this respect.

The manner in which the animal charcoal acts in the production of these results is quite incomprehensible. Its chemical characteristics seem to be unchanged, nothing appears to have been added to it in chemical combination, nor does any thing seem to have been abstracted, except those powers themselves, which are however restored, either by fermentation or by re-burning.

If we look to its chemical composition for a solution of the effects produced, we receive no information, for it consists of charcoal, 10; phosphate of lime and carbonate of lime, 88; silica and iron, in the state of an oxide, 2.

Many other bodies, as chlorine, sulphurous acid, alumina, &c., have the power of destroying certain organic colouring matters; but none of them can discharge that colour from syrup which is induced by its continued exposure to a high temperature: animal charcoal being the only agent at present known possessing this property.

The beneficial results obtained by the action of animal charcoal on the syrup obtained from cane-juice, are — 1st. Decoloration, which extends both to the sugar and molasses. 2d. Abstraction of any excess of lime which it may contain. 3rd. The neu-

tralisation of any free acid. 4th. The removal of nitrogenised matters. 5th. The amelioration of that viscid condition which inspissated cane-juice frequently presents. 6th. The promotion of granulation.

It follows, therefore, that the employment of animal charcoal enables us to obtain a larger amount of sugar, and a great improvement in its quality. The molasses, also, in consequence of the lightness of their colour and their freeness from viscidity, are, when the syrup from which they were produced has been thus treated, fitted to yield in their turn a very superior quality of Muscovado sugar.

It is, however, on the syrups obtained from the beet-root that the action of animal charcoal is the most decided, and the benefits resulting from its use most clearly evinced. Indeed it may be doubted whether, deprived of the assistance rendered by this substance, that branch of industry could be pursued with profit.

There has been no such urgent necessity for its employment in the colonial boiling-houses, which, coupled with the expense attendant upon its introduction, has caused its perhaps unmerited neglect there. But if it can be employed with economy and great benefit in the refineries in Europe, it is surely worth inquiry how far the same results may be obtained in the colonies.

Were animal charcoal extensively employed throughout the West Indies, a new branch of industry must necessarily accompany it; namely,

that of its manufacture and re-burning. There would be no difficulties met with in this respect.

There are certain varieties of charcoal, which, so far as regards the decoloration of syrups, possess powers scarcely inferior to bone black. Of these, the one which results from the destructive distillation of bituminous shale is pre-eminent. I have made many experiments with this variety of charcoal on syrups of different kinds, and have invariably succeeded in improving their colour to a very considerable degree; but it is said not to possess to an equal extent the property of separating the lime and albuminous principles. Such, it is probable, is the case, and the benefit derived from its employment in the manufacture of beet-root sugar would therefore be limited; but as the syrups from well-defecated cane-juice contain those substances in very minute quantities, these objections may not be equally applicable to them. The properties of this substance are improved by re-burning, and its price would not exceed the fourth of that of animal charcoal.

The asphalte of Trinidad, submitted to destructive distillation, affords an excellent charcoal which there is every reason to believe possesses considerable powers in discharging colour from syrup.

Although vegetable charcoal in its ordinary state is of little value as an agent for bleaching saccharine liquids, its powers in this respect may be considerably augmented by proper management.

Let 30 lbs. of it, reduced to a fine powder and then washed carefully in water slightly acidulated

with muriatic acid and afterwards with pure water, be mixed with 70 lbs. of clay, in the form of a paste, and the whole be set by to dry; then let it be broken into small pieces, and calcined in a close iron vessel at a white heat for two hours. On its withdrawal it must be received in covered iron boxes out of the contact of the air, or instantly cooled with aspersions of cold water, and reduced into a coarse powder. This forms an excellent substitute for animal charcoal, as it possesses considerable discolorating powers.

There is also another preparation which answers this purpose tolerably well. Take 100 parts of clay, prepared as above, 40 parts of tar, and 500 parts of common coal bruised very small; blend the whole into an uniform mass, dry in the sun, break it into pieces, and calcine in a retort.

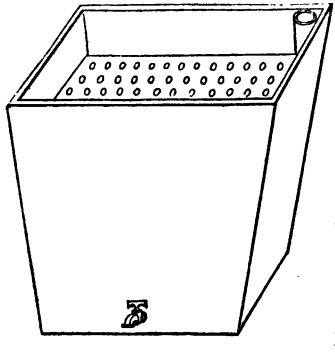
Both the above preparations can be employed in the way of filtration only.

Their powers, when enervated or destroyed, may be renewed by reburning.

The advantages derived from the use of animal charcoal in the boiling-houses of the West Indies, were they confined to the discharging of the colour from the syrups merely, would be so considerable, from the increased value of the products, that it is surprising its introduction has been on so limited a scale. Its great price as an article of commerce, and the labour and trouble entailed by its repeated calcinations, have operated, it must be admitted, as powerful reasons against its more general employment.

If, after due evaporation, it is decided to pass the syrup through charcoal, one of the following plans may be pursued:—

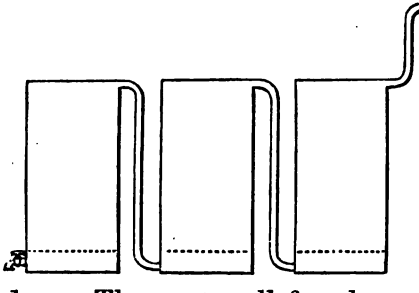
Dumont's filter consists of a quadrangular pyramidal vessel, made of wood, the base being uppermost. It has a double bottom, the upper one being composed of a piece of basket-work, or a perforated metal plate. In the space between the two is inserted a cock, and a metal tube which rises to the same elevation as the vessel itself, also communicates with this part of the apparatus. Upon the perforated false bottom a piece of flannel is spread, on which the animal charcoal, reduced to the state of a coarse powder, or in grains, and moistened with a little water, is carefully and evenly spread, until about two thirds of the vessel is filled with it. Over the charcoal is placed a perforated cover or a piece of basket-work, and the filter is fit for use.



The hot syrup is now poured in, and allowed to percolate slowly through; the air and water being forced onward by the pressure, escape through the tube. On arriving within the space between the true and false bottom, the cock is turned, and the filtered syrup escapes. These vessels are about three feet wide at the top, two feet at the bottom, and about three and a half feet deep. Four such would be required to be in use in a boiling-house

making three hogsheads of sugar per diem. They may be employed for three or four days successively: after that period the charcoal requires to be revivified.

Peyron's filters.—These filters are composed of a series of cylindrical copper vessels, each having a double bottom, as those of Dumont, and being hermetically closed at the top. They are closely packed with animal charcoal, and into the upper part of the first vessel is introduced a pipe for the admission of the syrup, which is made to descend from a sufficient height, or which is forced in by means of a pump in such a manner that, from the pressure employed, it passes rapidly through the charcoal, and is received by the space between the two bottoms. Here it enters another pipe, which conveys it to the upper part of the second filter placed close by. Thus it continues through the whole series, until it is at last drawn off by a cock placed for the purpose in the last vessel.



Each of the cylinders is six feet high, and three feet in diameter. Three of them would be required in a boiling-house making three hogsheads a day. They act well for about five or six days.

The charcoal is never removed from them; but when its powers require to be restored, boiling water is introduced for the purpose of washing

away as much as possible the syrup remaining in the interstices. The sweet liquid which comes away is thrown into the evaporating vessels, while the filters are put into some warm place that fermentation may ensue. It is stated, that this fermentation is completely terminated after twenty-four or thirty-six hours. In this way, the organic matters which had neutralised the decolorating powers of the charcoal are destroyed; and to restore its properties nothing now is required but an effective washing. This is best performed by the injection of high pressure steam for half an hour; when steam is not used in the boiling-house, hot water must be passed through in a continued stream until it comes away clear and limpid.

These filters have answered their purpose very well both on the Continent and in London; but strange to say they exert little action upon syrups obtained from the beet-root. They appear, however, to be well suited for the colonies.

The simplest, and certainly not the worst kind of charcoal filter, is one that can be made in a moment on any estate. Take a clean rum puncheon, and at the distance of two or three inches from the bottom, make a support sufficient to retain a piece of basket work, corresponding in size to that part of the cask. Into the space between this and the bottom affix a cock. Fill the cask up to about two thirds of its height with charcoal, carefully, so as to avoid all inequalities of surface, and cover it with another and similar piece of basket work. The filter is now prepared. Introduce the hot

syrup gradually and cautiously until the puncheon is entirely full; let it remain in contact for two hours, and then turn the cock. The first portion of syrup that comes away will contain minute particles of charcoal, it should therefore be returned to the evaporating vessels.

Four puncheons, so arranged, would be required for an ordinary boiling-house. The other filtering substances described above answer very well when used in this way.

The filters should be placed as near the vessel or vessels employed for the evaporation of the cane-juice as convenient, and on an elevation somewhat above that of the copper wall, to allow the passage of the syrup into some convenient receiver. They may be filled, either by a short barrelled force-pump or by a *monte-jus*.

CHAP. V.

CONCENTRATION OF SYRUP, AS AT PRESENT PRACTISED. — IN A SEPARATE TEACHE. — CHAUDIÈRE À BASCULE. — BY STEAM. — AT A LOW TEMPERATURE. — VACUUM PAN. — KNELLER'S PAN. — GADESDEN'S PAN. — APPEARANCES OBSERVED WHEN CONCENTRATING HEALTHY SYRUP, ACID SYRUP, ALKALINE SYRUP, SALINE AND VISCOUS SYRUP, AND ALBUMINOUS SYRUP.

By the performance of the before-mentioned operations on the cane-juice, a syrup will have been produced. This syrup may or may not have been filtered through animal charcoal. In the first case its density will be 27° or 28° Beaumé, being the degree best suited for that purpose; the relative amount of its constituents will be 50 parts of sugar and 50 parts of water in 100, and the temperature of its boiling point will be 219° or 220° Fahr. In the second case the density of the syrup will be somewhat greater, and it may conveniently be stated at 32° Beaumé; then the amounts of its sugar and water will be as 60 of the former to 40 of the latter in 100 parts, and its boiling point will be 224°.

Syrups having these degrees of density may be exposed for a short time to a temperature equal to the one above, without the occurrence of much injury; but if the period of its exposure be protracted, or if its temperature be augmented (a necessary consequence of its increasing density by a

continued ebullition), changes in the composition of the sugar will, as formerly shown, inevitably ensue.

These changes will be produced even in the purest syrups when thus treated, but they take place more rapidly, and exist to a greater extent when the syrup holds in solution those organic and saline substances which are found in cane-juice.

For this reason the process described as *evaporation* should now cease, and should be replaced by another for the purpose of continuing the inspissation of the syrup to a point somewhat beyond that of its perfect saturation when boiling. Although this operation cannot be effected without evaporation, it demands the application of some plan by which it may be performed with the smallest possible risk of the occurrence of those changes which are so liable to result from a high temperature.

We have already seen that sugar is soluble in $\frac{1}{2}$ its weight of cold, and in $\frac{1}{3}$ of its weight of boiling water; consequently boiling syrup when thoroughly saturated, must deposit on cooling, $\frac{3}{5}$ of its sugar, the remaining $\frac{2}{5}$ being held in solution by the water. In other words, a boiling syrup composed of 5 lbs. of sugar, and 1 lb. of water, will, when it becomes cold, have deposited in the form of crystals 3 lbs. of solid sugar, the other 2 lbs. being dissolved in the 1 lb. of water, thus constituting 3 lbs. of mother liquor or molasses.

The temperature required for the ebullition of a syrup, consisting of 5 parts of sugar and 1 part of water, varies according to its purity from 238°

to 239° Fahr. But as it is desirable in sugar-making to carry the evaporation somewhat beyond the point of saturation, the temperature of the boiling syrup, when of the density usually required, is 240° or 242°, and occasionally somewhat higher.

Syrup cannot be submitted to this temperature without sustaining injury.

If we take a quantity of sugar in the state called crushed lumps, which is one of almost entire purity, and after dissolving it in an equal weight of water so as to form a syrup, submit it to evaporation in a flat-bottomed copper pan over a naked fire, using the greatest care that the bottom of the pan alone be exposed to the fire, we shall perceive that little change takes place in its appearance at first, but in a short time, as the liquor approaches its granulating point, it gradually acquires a yellowish tint, which becomes deeper, and assumes a reddish colour as the process continues. The same results are observed if, instead of an open fire, high pressure steam be employed to effect the evaporation. In neither case, it is probable, has the temperature of the liquid exceeded 240°.

In the *Journal de Pharmacie* for 1842 will be found an account of some most interesting experiments made by M. Soubieran, to illustrate the effect of heat on saccharine liquids. That gentleman exposed syrups to the action of heat in an apparatus so constructed, that as evaporation went forward the water was returned to the sugar almost as soon as it was separated, and the uniform density of the liquid was consequently preserved. The

changes produced in the sugar were tested by means of the polariscope, and the following results were observed: —

Syrup, primitive rotation - -	+68°
„ after 18 hours - - -	+54
„ „ 48 „ - - -	+20
„ „ 90 „ - - -	— 7
„ „ 114 „ - - -	—16
„ „ 138 „ - - -	— 6

The syrup now became black and acid. It held suspended in it, and also deposited as a precipitate, a dark brown or black powder. The sugar was entirely decomposed. In another experiment the results were: —

Syrup, primitive rotation - -	+71°
„ after 18 hours - - -	— 8
„ „ 36 „ - - -	—15

The effects in this experiment were much more rapid, as the syrup was exposed to the heat of boiling muriate of lime.

There is no necessity for presenting to the reader a detail of all the experiments performed. It will be sufficient to state, that each of them showed a result corresponding with the above.

These results consisted, 1st. In the gradual disappearance of the cane-sugar. 2d. In its being replaced by glucose or the sugar of fruits. 3d In the production of a black carbonaceous powder, and formic and acetic acids.

It was also shown, that these changes were prompt in direct ratio to the degree of heat which the syrup attained, and to the state of concentration of the latter.

The presence of lime in pure syrup retarded the changes, but if only a very small quantity of glucose was found combined in the syrup, lime, on the other hand, tended rather to hasten them.

M. Soubieran next inquired whether these changes took place during the process of refining Muscovado sugar. With this purpose he visited an establishment in the neighbourhood of Paris, in which the syrups were concentrated at a low temperature (*in vacuo*). He then discovered, that by this treatment the syrup underwent no change, and that the glucose originally contained in the Muscovado sugar passed entirely into the treacle.

Another evil to be avoided in the concentration of syrups of high density, is that of caramelization or burning. It may be said, that by ordinary care and attention, the risk of producing this effect, even when the operation is carried on in an open vessel exposed to the direct action of the fire, is not great; but those who are acquainted with the mode of concentration practised in the West Indies know that this accident is unavoidable in those boiling-houses in which the common plant is in use.

In studying this branch of our subject, three circumstances must be attended to; namely, the apparatus best suited to perform it, the kind of syrup to be operated upon, and the knowledge or skill of the person operating.

It is of the highest importance that every process which enters into the art of sugar-making should be well and completely performed; but if there be one among them to which this is more applicable than

to another, it is probably that of concentration. Fortunately, this operation has attracted much attention, and the means devised to perform it have consequently been much ameliorated.

As now conducted in the colonies, with very rare exceptions, concentration is merely the last stage of evaporation to which the cane-juice is submitted in the first copper, or, as it is called, the teache. This vessel, like all the others which adjoin it, is in form the segment of a hollow sphere; its upper rim is surrounded by a lip or flanche, by which it is suspended over the furnace below. The mason work into which this flanche is inserted, is constantly in a glowing heat, so that damping or even withdrawing the fire is insufficient to extinguish the intensity of the temperature to which the syrup in this vessel is always exposed.

By such an arrangement concentration may, it is true, be effected with considerable rapidity, but never without inducing great loss both in the quantity of sugar produced and also in its quality.

The amount of loss from this cause alone it would be difficult to estimate with accuracy, indeed it varies much in the different colonies, but it may with safety be estimated at 10 per cent.

In Barbadoes an attempt has been made to remedy many of the evils arising from the action of intense heat upon the contents of the teache, and with some success. It consists merely in diminishing the size of the vessel, so that by increasing the number of skips in a given time, the syrup, from the shorter time required for its sojourn in the vessel,

is less liable to change than it would be were the vessel larger and the skips less frequent.

I have, when speaking of evaporation, shown the necessity of removing the teache from the other coppers, and of entirely separating from each other two operations which cannot be performed simultaneously. I have now merely to add, *that this is indispensable.*

The colonial sugar-boiler does well in exercising his judgment upon the propriety of adopting or rejecting new schemes, a new plant, or new machinery; but he certainly can have little judgment to exercise if he continue much longer the present method of concentration in a spherical pan placed over the same fire that heats the other coppers.

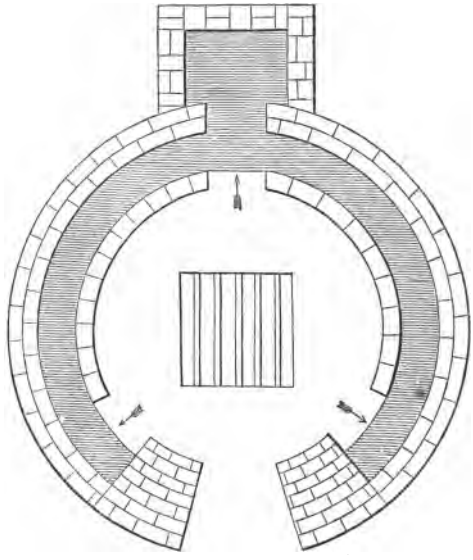
It would be useless to enumerate all the evils that thence arise, for they are too well known, and too generally admitted to require it; our time will be better occupied in trying to obviate them by means as simple and at a cost as small as possible.

The first improvement upon the present method, therefore, consists in placing the teache over a separate fire, and in giving it a slight modification of form. In the latter respect, it should be a circular vessel about 45 inches in diameter, and 14 or 15 inches in depth, the bottom of which should be slightly convex, that is, arched upwards; and it may be supplied with a cock for drawing off the syrup when duly concentrated.

The bottom alone should be exposed to the fire, and to accelerate the operation, this part may be

corrugated or studded with metallic knobs, as before described.

The fireplace may also be modified with advantage, and probably such a plan as the one indicated by the accompanying diagram would be found well suited for the purpose; it is copied from Mr. Porter's work on the sugar-cane.



By this arrangement, the heat is more equally distributed over the bottom of the pan, in consequence of the products of combustion being obliged to pass through the different openings into the flue, previously to their escape into the chimney.

The teache, so fitted, resembles somewhat the concentrating pan of the refiner of bygone days. We can by its means modify the heat applied, without interfering with the evaporation going on

in the other vessels, and the bottom alone being exposed to the fire, there is much less risk of charring or burning the sugar than in the method now in use.

Some years ago a concentrating vessel of a peculiar shape was much in use in the refineries and sugar houses in France. From the way in which its contents were evacuated, it was called a *chaudière à bascule.* It was a shallow pan, having a mouth-piece or spout, and resembled in shape somewhat a common coal-skuttle.

It was placed upon, but not fixed into, the mason work of the furnace; it was however attached to it, anteriorly, by means of an iron bolt, in such a manner, that a certain motion was permitted around this point. To the back part was fixed a rope, which passed over a pulley, by which means the vessel could be tilted up, and its contents poured into any receiver.

The furnace on which it was placed resembled in principle the one last described.

The superiority which this pan presents over the former consists in the facility by which its contents are removed from the action of the fire at the time of skipping. It has never, I believe, been in use in this country; and even in France, where it was once extensively employed, it has been entirely superseded by more improved inventions.

Steam has been of late very generally used on the Continent, as a means of concentrating the syrups from the beetroot by ebullition under ordinary atmospheric pressure.

The various kinds of apparatus that have been constructed on this principle are far too numerous to mention, and the greater number have already fallen almost into oblivion. Those which have best succeeded consisted of pans of different forms, into which the steam was introduced either by a false bottom or by a spiral tube. The latter mode is preferable.

A concentrating vessel on this plan, when well constructed, evaporates with very great rapidity. Its employment, also, is necessarily unaccompanied either by charring or the production of caramel from sudden or intense heat; for the heating surface is immersed in the liquid to be heated, and is never of a temperature sufficiently high to produce its immediate decomposition. For these reasons concentrating vessels of this kind have been most strongly recommended.

But we must remember that the temperature is equally as high in syrups which are caused to boil by means of steam, as in those in which this action is produced by immediate contact with the fire, and that in syrup of high density this temperature is sufficient to convert a large portion of the sugar into glucose in a short space of time.

So far as I can learn, the introduction of these vessels into the colonies has not been attended with any considerable success; which, coupled with the want of adequate skill to repair the apparatus when out of order, has operated against their more general employment.

Indeed an injury to the steam pipe sufficient to allow the smallest possible escape of steam of high pressure into the syrup would be followed by results far more injurious than what daily occur in the common teache from the application of the fire of the furnace.

Should the proprietor of a sugar estate be desirous of using high pressure steam in his boiling house, it must be better worth his while to do so at once judiciously and effectively, by combining it with the advantages derived from a diminished atmospheric pressure, although at a somewhat greater cost.

I cannot, therefore, recommend this description of teache; for the advantages which it offers over the chaudière à bascale, or even over a well-constructed copper vessel placed upon its own furnace, are not on the whole balanced by its greater cost in the first instance, the increased expense attendant upon its application subsequently, and by the additional trouble and labour incurred by its introduction into a boiling house for the accomplishment of so *partial* an object.

By the above methods the concentration of the syrup is effected by an active ebullition under the entire pressure of the atmosphere, consequently at a temperature so high, that the operation must be carried on with great rapidity, otherwise the sugar would receive great injury, although that produced by charring or burning would be obviated.

To prevent the occurrence of the evils arising from a high temperature, Mr. Howard, in the year

1819, took out a patent for concentrating saccharine liquids "*in vacuo*."

It is well known that liquids boil at a temperatute inversely proportionate to the pressure exerted on their surfaces. If we take a Florence flask containing a little water, and hold it over the flame of a spirit lamp until the water boils and the steam escapes freely, then suddenly remove the lamp and cork the flask carefully, it will be perceived that the water will cease to boil, but that on plunging the flask suddenly into cold water, ebullition will recommence, and that it will again cease on holding the flask over the lamp. In this experiment the air is driven out of the flask by the steam, which forms an atmosphere of its own in the upper part of it. When the flask is corked and plunged into the water the steam is condensed, a vacuum is formed, and the water begins again to boil, because the pressure has been removed from its surface.

Mr. Howard took advantage of this fact, and reduced the experiment to practical utility. For the purpose he had in view he invented an apparatus consisting of a globular copper vessel, enclosed within an iron or copper jacket, and between the two steam was introduced to heat the syrup contained within the former, which was the boiler or concentrator. To this was affixed a tube for the escape of the vapour as it arose, which was condensed by a jet of water introduced for the purpose. An air pump was likewise attached to form the vacuum in the first instance, and afterwards to get rid of the condensed vapour.

Many improvements have been added to the original design of Howard, but the principle has always been retained. The essential ameliorations, however, may be confined to two—the heating of the syrup by a long coil of steam piping introduced into the interior of the pan, and the condensation of the vapour, and its ultimate escape by means of an extensive metallic worm, kept cool by the continued pouring of an artificial rain.

I cannot enter into a description of all the modifications that this method of concentrating has been made to undergo. That information can be much better supplied by any of the large coppersmiths who are in the habit of manufacturing the various kinds of apparatus applied to the manufacture of sugar.

Every vacuum pan should be furnished with a thermometer to point out the temperature to which the syrup contained within it is exposed, and a barometer to measure the amount of exhaustion produced in the vessel. It is customary to consider this exhaustion as a force, and to describe its degree by the number of inches that the mercury in the tube rises to, less than would be produced by the pressure of the atmosphere at the time. For instance, if the pressure of the atmosphere be equal to 30 inches, while that within the partially exhausted concentrator be equal to 3 inches only, it is usually said that an amount of vacuum or exhaustion has been obtained equal to 27 inches of mercury, that being the difference of pressure exerted in the respective cases.

There is no mode of concentrating syrups at present known which offers advantages equal to those of the vacuum pan, when well constructed and in good working order. For to a very large heating surface resulting from the steam jacket and the extent of steam pipe, inserted in the interior of the vessel in the manner of a closely packed spiral, is added the greatly increased evaporating power caused by the diminished pressure on the surface of the liquid.

It has been proved that for every $\frac{1}{10}$ of an inch that the barometer rises or falls, there is a corresponding rise or fall of the boiling point of water equal to $\frac{176}{1000}$ of a degree, and consequently that where that fall is equal to 27 inches, the boiling point of water, instead of being at 212°, must be at 164°·5. Under such circumstances a rapid concentration of cane syrup can be effected at a temperature ranging between that point and 180° Fahr., and, as the experiments of M. Soubieran have shown, without the accompaniment of any change in the chemical composition of the sugar.

This plan of concentrating syrup embraces the two conditions essential to the successful performance of the operation, namely, rapidity and a low temperature.

Unfortunately its general adoption, that is, its introduction on every estate, will for ever be impossible, in consequence of the great outlay required for the purchase of the apparatus, the skill required for its management, its liability to get out of order,

and the necessity of more efficient workmen for its repairs, than are as yet to be found in the colonies. The first of these objections is not so applicable to large estates as it is to small ones, as they offer a larger scope for getting the return of an adequate interest on the money so invested; and in such a case the others would be overcome by the necessity which would arise of obtaining that knowledge from abroad which is not to be had at home, were there an urgent demand for its supply.

There can be no doubt that, on those estates which, from their extent and the fortunate position of their owners, will admit of the sinking a capital sufficient to obtain the vacuum apparatus, in conjunction with steam defecating and evaporating vessels, and a powerful and well-constructed mill, the ameliorations which would result, both in the quantity and the quality of the products, obtained under a prudent and intelligent management, would fully compensate the expense incurred; but how few are the estates which at the present time are in such fortunate circumstances!

Some years ago Mr. Kneller patented an invention for concentrating saccharine and other liquids. The apparatus consisted of a pan, into which were introduced a number of pipes for the purpose of conveying air into the liquid to be evaporated. The air was forced through the pipes by means of bellows or any other blowing contrivance.

M. Brame Chevallier effected considerable improvements in this plan, by substituting high pressure steam for the naked fire as a heating medium,

and hot, or rather dry air, for the cold and humid air of the atmosphere.

This method of concentrating syrup has been in use both in England and in France, although now discontinued in both countries.

The operation was rapid, and the temperature was preserved between 180° and 190°. It is probable that if the vacuum pan had not been known, and in general employment at the time, the introduction of this plan would have met with greater encouragement.

But the results obtained by the latter were not equal to those of the former, whilst its first cost was little inferior, and its working expenses, &c., were quite as great.

Mr. Augustus Gadesden, one of the most intelligent sugar refiners of London, introduced, some months since, to the notice of the West India proprietary body resident in the metropolis, a plan for concentrating syrup at a low temperature over the open fire, and at the ordinary pressure of the atmosphere.

This gentleman's apparatus consists of an iron or copper pan, having nearly the form of the half of a hollow cylinder, in which is placed a drum or wheel adapted to the shape of the vessel, and formed of a number of metal rods, so arranged that the evaporating surface given to the syrup is increased as much as possible. The wheel, half its circumference being immersed in the liquid, is kept constantly revolving; so that by exposing fresh portions of the heated syrup to the action of

the atmosphere at each succeeding revolution, the evaporation of the aqueous particles is rendered more rapid than it otherwise would be while the temperature is at the same time in a corresponding degree reduced.

The time required to take off a skip in a pan containing one ton of sugar varies from two and a half to four hours, and the temperature of the syrup varies from 150° to 180°.

From the principles on which this method of concentration are based, it is evident that its successful working will depend upon the degree of dryness of the atmosphere, and on the rapidity with which the air passes over the surface of the syrup. The apparatus should therefore always, when it is practicable, be placed at the windward side of the boiling house, at all events it should be beyond the influence of the vapours which arise from the evaporating vessels.

I used a small concentrating vessel of this description in the island of Madeira. The time required for taking off a strike containing fourteen moulds of fifty pounds each was two hours, and two hours and a half. The results were highly satisfactory; the temperature never exceeded 160°. It has also been in operation during two crops in Berbice, where its success appears to have answered every expectation formed of it. Such, however, has not been the case in the trials made of it in Barbadoes, for accounts from that island state that it occasioned a considerable amount of froth, and

that the time occupied in taking off a skip was longer than was contemplated.

In Berbice the pan was worked by an intelligent boiler-man sent out from this country for the purpose; in the latter instance its management was intrusted to the sugar boilers of the colony.

The frothing no doubt was owing to the incomplete defecation of the cane juice, and the non-separation of the whole of the albuminous principles; if so, the addition of a drachm or two of washed butter would in all probability have proved a remedy.

In the prospectus it is stated, that this method of concentration is not intended to supersede the vacuum process, but that it is recommended as a cheap and valuable substitute for it on estates where, owing to its high price, the latter cannot be introduced with advantage.

The great simplicity of its construction and its easy management certainly recommend this pan, if it is found in other respects to answer equally well the purposes proposed.

In whatever vessel the concentration may be performed, it is an operation which always requires considerable skill and ability to conduct properly. It is in this stage of the manufacture that the benefits derived from the careful defecation and evaporation of the cane-juice will be evinced; for the difficulties will be slight, if those operations have been efficiently performed, compared with those which are certain now to arise if negligence

or carelessness have been evinced in the antecedent stages.

When concentration is performed at a high temperature, that is, by ebullition under the ordinary atmospheric pressure, whether the heating medium be the naked fire or high pressure steam, our principal object ought to be to arrive at "*proof*," with as little delay as possible. This should likewise be our object when the operation is performed at a much lower temperature; but in the latter case expedition is not of such extreme importance, and we therefore have it in our power to induce crystallisation of the sugar simultaneously with the concentration of the syrup.

The term "*proof*" is applied to certain appearances which indicate that the syrup has arrived at the degree of concentration required for the deposition of at least $\frac{3}{5}$ of the quantity of sugar which it contains. It is obvious that these appearances will be modified according to the purity or impurity of the syrup and its stage of concentration.

When the cane-juice is of a healthy character, and when all the preceding operations have been well performed, the following appearances are observed during its concentration in the open pan. The boiling syrup is clear and transparent, it does not mount or rise in foam or froth, the ebullition is quick and sharp, the bubbles succeeding each other with rapidity, and bursting as they arise. As the inspissation advances, the syrup is seen to run from the edge of the skimmer in a thin broad sheet, which separates as if it were cut sharply off with a

pair of scissors, and never hangs down in long adhesive strings; it communicates to the eye the sensation of being a sharp, short crispy fluid possessing little tenacity or viscidity, and the sound of its ebullition communicates to the ear a similar idea.

On taking a very small quantity of syrup as it approaches proof between the forefinger and thumb, and permitting it to remain until sufficiently cool, we shall perceive on separating these parts from each other,—1st, that it divides into two small portions or drops, the lower one of which, attached to the thumb, is larger than that adhering to the finger; 2d, that the portions become pretty nearly equal, and their division is effected by a wider separation of the finger and thumb; 3d, on a separation to the extent of half an inch, a slight column of syrup is produced which remains for an instant, and then breaks at its inferior extremity; 4th, a thin thread is produced on a somewhat wider separation, and on breaking the extremity curls up in the form of a hook, and gradually retracts to the portion which remains on the finger; 5th, on a still wider separation the thread on breaking is so thin as to be scarcely perceptible at its lower end, which is drawn upwards in the form of a corkscrew.

If the concentration be carried a little beyond this point, the thread when broken does not retract upon itself.

The thermometer, as the inspissation proceeds, will indicate a temperature from 236° to 242°; and

the proportion of water contained in the syrup will be, in the instances denoted by Nos. 1 and 2, 16 parts in 100, while in the 5th it will be less than 10 parts in 100.

The latter is the highest proof that can with safety be given to syrups by concentration over the fire; in the colonial boiling-houses the proportion of water is rarely reduced below 12 per 100.

When concentration is performed at a low temperature, the amount of water may be very much diminished, indeed it may be entirely dissipated, and the sugar may be obtained in a perfectly dry state.

It is not, however, judicious so to do; and the best *point* that the sugar boiler should seek to obtain is that in which the relative amounts of sugar and water are as 90 to 10. In this case the amount of crystallised sugar obtained will be 70 lbs., and that of molasses 30 lbs., in every 100 lbs. It may frequently happen that this point will be too high, and that a better result may be obtained by allowing the concentrated syrup to be a little more *free*.

There appears to be an opinion pretty generally received, that by "*boiling stiff*" at a low temperature there is considerable economy in fuel, time, and labour, and that the extract obtained is greater. This is an error; for in all these respects the results are much the same, whether the operation be a continuous one, or whether it be conducted twice or thrice over.

I mean, that if, after having obtained as much of the sugar as is produced by a primary crystalli-

sation of the syrup, we submit the mother liquor which escapes to a second concentration and crystallisation the quantity of fuel will not be increased, the time required for the effective drainage or curing will be shorter, and the labour will be to a very small degree only augmented, whilst the amount of extract will be equally great, and its marketable value will be higher.

There is also another object which the sugar boiler attempts to obtain while concentrating syrup at a low temperature; namely, the simultaneous production of the crystallisation of the sugar. This should always be effected, if possible. For this purpose, the operation should commence upon a comparatively small quantity of syrup. The pan should be filled only to one third of its capacity, syrup being slowly added as the evaporation of its water proceeds, until incipient granulation commences, which is known by the appearance of *spark*, that is, the reflexion of a ray of light from an incipient granule exhibited in the syrup when drawn between the finger and thumb.

When *spark* is perceived, a fresh charge of syrup is to be added, and the concentration should be pushed until a portion of the sugar is crystallised.

The supply of syrup should be continued (but always in small quantities at a time, care being taken that the grain, having once formed, is not redissolved,) until the pan is sufficiently full, when the skip must be taken off, should it in the opinion of the boilerman be duly concentrated.

The judicious performance of this operation re-

quires both practice and skill, neither of which can be acquired from any written description.

The foregoing remarks are applicable to cane-syrups of good quality, and which have been properly defecated and evaporated. But how frequently does it happen that syrups are found to have a very different character from the above, and to offer other appearances during their concentration!

Acid Syrups may arise from many causes: 1st, from disease or injury in the canes; 2d, from the incipient souring of the cane-juice; 3d, from the deficient quantity of lime employed in defecation, &c. From whatever cause the acidity may have arisen, syrups of this kind generally want transparency, and their dimness or muddiness increases as the evaporation goes forward. They boil tolerably freely at first, but as their density increases the ebullition is less brisk, and the colour becomes somewhat darker. The latter is more remarkably the case during concentration, when this operation is effected at a high temperature; but if it be conducted *in vacuo*, or by other means which permit of its performance at a temperature of 160° or 170°, the colour is little heightened. When this evil exists only in a moderate degree the sugars have a light colour, but the grain is small, and they do not cure quickly. The molasses are more abundant than the point to which concentration has been carried would indicate, and their crystallisation is often difficult to effect.

The remedy for this condition of the syrup

would be the addition of a little lime-water during the evaporating process; but its prevention in the first place, and where that is impracticable (if it ever be), the neutralisation of the acid in the clarifiers, should be effected.

Alkaline Syrups may be caused by the too abundant addition of lime to the cane-juice, either in the clarifiers or afterwards. When this evil exists in a moderate degree only, the injurious consequences may be confined to the production of too dark a colour in the syrup, and in the sugar obtained from it. The grain of sugar produced from such syrup is generally good, and the molasses separate readily.

When the excess of lime has been very great, or when this substance has been employed so as to completely neutralise cane-juice in which the lactic acid fermentation has commenced, the syrup during concentration will probably present features resembling those which are observed in what may be called—

Saline and Viscid Syrups. This state of the syrup results from many causes, which have been explained in the first part of the book. Any thing, in fact, which causes an unusual excess of the saline constituents in the cane-juice, as their absorption from the soil or their formation by the addition of lime to neutralise cane-juice which has become sour, or whatever may establish the viscous fermentation in this fluid, must be so regarded. When thus affected, the concentration of the syrup at a high temperature is often impracticable. It is

viscid, gummy, and adhesive, running from the ladle or edge of the skimmer in long strings.

Its ebullition is very irregular and very slow; the bubbles seem to traverse half the surface of the liquid before they burst; they appear like large adhesive blisters, which not unfrequently collapse, and for a moment leave the heated mass in a state of repose. I once witnessed a syrup of this kind burst into flame from the fire under the teache being urged with a hope of expediting the concentration.

The sugars produced are dark, heavy, clammy, and deliquescent. Occasionally their granulation will not take place at all.

Syrups of this kind demand concentration at a low temperature; it is the only means by which can be obtained from them a remunerating quantity of a marketable extract.

Albuminous Syrups. From imperfect defecation a small quantity of albumen and caseine may remain dissolved in the syrup; and for reasons already explained, this may be caused either by the presence of an acid or an alkali.

Albuminous syrups always produce during their evaporation and concentration a large quantity of froth, which rises faster than the skimmer can take away, and is often the source of considerable annoyance. The addition of a small quantity of butter or sweet oil will generally cause the froth to disappear, as if by magic, and the rest of the operation to go on favourably. The presence of the small quantity of this substance sufficient to effect

the purpose is not injurious; on the contrary, it seems to facilitate the process of curing.

It occasionally happens, that after due concentration the syrup, instead of showing a disposition to granulate, assumes the appearance of a semi-fluid substance of great tenacity and adhesiveness, such as we may suppose would be produced by a mixture of equal parts of mucilage and sugar.

The term "*smear*" is applied by sugar refiners to syrups of this kind.

It is a condition not confined to impure syrups only, but it likewise occasionally occurs in those of the greatest purity. It takes place, however, much more frequently in the former, particularly in those which contain a large quantity of saline matters, as in green syrups, molasses, &c.

The real nature of *smear* is not known. It probably depends upon some electro-chemical change excited in the molecules of the sugar during the process of concentration; but which, however, is not permanent, for syrups thus affected will, if left to themselves for some time, gradually become more and more crystalline; or if they be diluted by the addition of a little water, and be again concentrated, granulation will ensue, as if nothing had previously happened. Generally their exposure in a heater for a short time to such a temperature as will preserve their fluidity is sufficient to destroy this character, and to restore the crystalline powers of the sugar.

Before commencing another chapter, I must remind the sugar-boiler that whether he concen-

trates his syrups highly or the reverse, that is, to a point that indicates the amount of water at less than ten per cent., or to one that shows this quantity to be somewhat greater than twelve per cent.; in other words, where the molasses will be less than thirty per cent., or greater than thirty-six per cent., he must not lose sight of the process which is to succeed, and to the effective performance of which the syrup, during concentration, ought to be adapted; namely, the complete separation of the mother liquor, or molasses, from the sugar with facility and despatch.

I believe that this point has not been sufficiently attended to by the persons in charge of the few vacuum pans which are at present in operation in the colonies. It is probably owing to this cause that the sugars hitherto produced by that apparatus evince, by their clamminess and stickiness, the imperfect curing which they have undergone, and which either diminishes their marketable value, or demands an expensive process of liquoring to remedy.

N.B. The foregoing calculations it may perhaps be necessary to state are based upon the supposition that syrup is composed of sugar and water only. But when foreign substances are likewise present, as is the case when the syrup is obtained immediately from cane-juice, some allowance must be made for the disturbing action produced by them, and which will be in direct ratio to their amount. The changes produced in the cane-juice during the various operations to which it is submitted when

conducted as they at present are will likewise cause other deviations from the rule. Thus we generally find that the quantity of sugar is less, and that of the molasses greater, than the amount of water contained in the syrup is sufficient to account for.

CHAP. VI.

CRYSTALLISATION. — POTTING. — METHOD AT PRESENT PURSUED. INJURIOUS CONSEQUENCES RESULTING FROM. — THEORY OF CRYSTALLISATION. — POTTING IN MOULDS. — IN CASES OR BOXES. — IN HEATER. — IN PNEUMATIC PAN.

IN the manufacture of sugar as at present pursued in the colonies, the syrup, after its due concentration in the teache, is passed directly into the coolers. This operation is denominated "*skipping*" or "*striking*," and is effected either by ladling, or by means of a copper skipper, a vessel so adapted in shape as to fit the interior of the teache, and to admit at once the contents of that vessel through a valve made for that purpose. The skipper when charged is rapidly raised by a crane, and it is supposed, that the great injury which the sugar is apt to undergo at this particular time, owing to the intense heat operating upon a highly inspissated syrup, is thus in a great measure prevented.

The coolers usually employed are shallow wooden troughs, varying in size from five to ten feet in length, and from three to five feet in width, but in depth they never exceed one foot or sixteen inches. In some of the islands these vessels are made of copper, but with what object I am ignorant.

Two skips at least, and usually several, are shot into each cooler, where they are allowed to remain

until granulation has commenced, and until the saccharine mass has acquired sufficient solidity to permit of its transportation to the hogshead, without risk of its leaking entirely into the molasses cistern.

During its sojourn in the cooler, the hot and inspissated syrup is occasionally stirred about for the purpose of mixing together the different skips, and to obtain throughout them a uniform temperature, in other words, to reduce them to the temperature of the surrounding atmosphere, with as little delay as possible. If such have been the motives which have caused the planter hitherto to treat his concentrated syrups in this manner, assuredly he could have devised no plan better suited to obtain his ends, for the position of the coolers in the boiling-house exposes their contents to the strong gusts of wind which are admitted on all sides into the building, and the shallowness of these vessels causes the heated syrup which they contain to present a very large surface to the cooling influence of the atmosphere.

By pursuing this plan, the inspissated syrup is most effectually and rapidly *cooled;* and as at the state of concentration to which it has been previously brought it contains a quantity of sugar more than sufficient for its saturation, the latter is deposited in an amorphous or semi-crystalline state, and diffused through the chilled and viscid molasses.

The half-crystallised sugar and the mother liquor or molasses being thus blended together,

form a doughy and homogeneous mass, which is cured with difficulty, and presenting in the sugar obtained an imperfect crystallisation, which is denominated by refiners false grain. Moreover, that portion of the molasses which escapes carries with it a large quantity of sugar, while that which remains adheres to each small particle of sugar with great tenacity, and is there retained by a kind of capillary attraction.

We see, therefore, that by pursuing the system now in use the *cooling* of the syrup is promoted, but its crystallisation and perfect curing are prevented.

When the mass of sugar and molasses has become sufficiently cooled, it is dug out of the cooler, shovelled into a bucket or some other vessel, carried into the curing house, and then thrown into the hogshead as if it were so much manure, where it remains until the drainage of the molasses is sufficiently complete to admit of its shipment. To assist the cooling process the curing-house is generally open to windward, and it is not unfrequently kept as cool as possible.

Had the planter intended to convert the cane-juice into dough or bird-lime, he could scarcely have invented a more successful method of accomplishing his purpose, but to obtain sugar a more ill-judged method, or one more defective in principle, could not be employed.

Concentrated cane-juice, even when in a state of the greatest purity, always contains a certain amount of saline matters, more or less soluble,

which, by their combining with sugar, form highly deliquescent compounds.

Whatever may be the reason, cane-juice is at present seldom admitted into the clarifiers free from a small admixture with lactic acid, which demands the employment of a large quantity of lime for its neutralisation.

Generally an excess of lime remains in the syrup, its separation not having been effected by the use of filters. In this way the quantity of saline matter is preternaturally increased.

Cane-juice likewise contains a considerable quantity of a highly hygroscopic organic substance, which I have called the deliquescent matter of Hervey.

These substances are not crystallisable, and were the concentrated syrup treated in a proper manner they would quickly separate from the sugar, and pass away in solution in the mother liquor. But by pursuing the present system all the constituents of the cane-juice are bound up together and form a homogeneous, pasty, and semi-crystalline mass, in which the vinous fermentation is sooner or later established.

The result is as might, *à priori*, be imagined. The sugar being bound up with these foreign substances gradually melts away like ice in warm weather. The drainage, which is seen issuing on all sides from the hogshead, does not consist merely of the mother liquor, that is, of the sugar held in solution by the water retained in the syrup, and the uncrystallisable and deliquescent saline bodies

above mentioned, but it is formed by the gradual melting of the entire contents of the cask — a bodily wasting away of the product of all our labours.

Thus a hogshead containing 200 imperial gallons of concentrated syrup will weigh about 2860 lbs. net, which ought to produce, if the manufacture had been properly conducted, 2000 lbs. of good sugar and 860 lbs. of molasses, deliverable in England, but which usually gives only 1680 lbs. of an imperfectly crystallised extract, and 660 lbs. of molasses, the remainder being the loss sustained by leakage, &c. From the 1680 lbs. of sugar, when it has been submitted to a process of refining, rarely more than 75 per cent. of crystallised sugar is obtained in the form of loaves, lumps, pieces, and bastards; there being 20 per cent. of uncrystallisable treacle and 5 per cent. loss.

This enormous loss in crystallised product, it is true, is not caused exclusively by the improper system of *potting* now pursued; it is caused in part by other errors also, committed in the antecedent stages of the manufacture. But it is to the former cause alone that the slow and imperfect drainage, the loss in weight occurring during the voyage home, the leakage of part of the crystallisable sugar, and the retention of the saline and other uncrystallisable matters, the presence of which is so injurious to the sugar, are owing.

It is said that the colonial sugar boiler, in pursuing the present method of potting and skipping, only follows the example of the sugar refiner of

former years, who skipped his syrup when sufficiently concentrated into a cooler, where it remained (being stirred occasionally with an oar) until crystallisation was established. There is, however, no parallel between the two cases. It was the business of the refiner to form his sugar into loaves and lumps; and it was necessary that they should be compact, and present a uniformity of grain. He was therefore compelled to skip his concentrated syrup into some vessel which would permit of its being stirred or moved about during the time that granulation was commencing. But he took every care that the syrup should not be chilled, and while still in a fluid state he poured it into the moulds in which the granulation was completed. Had he acted as the planter now does, the sugar would not have drained, the after processes would have been accomplished with difficulty, and would have been attended with a heavy loss.

Of all the branches into which the manufacture of sugar is divided, none admit of being so easily reformed as the one before us; but here, as elsewhere, a knowledge of the principles which should guide us in its performance is essential.

When the syrup has arrived at that point of concentration which is desirable, the next objects to be attained are, 1st, as large an amount of crystallisation as possible; 2d, as distinct and perfect a crystallisation as possible; and 3d, as a result of the two former, an easy separation of the molasses.

Crystallisation may be considered as a variety of the attractive force by which particles of similar

matter are drawn together, and are then so arranged that the whole puts on some regular and determined form; so that it not unfrequently happens that by a merely external examination of this form or crystal, its nature and composition may be ascertained.

To enable particles of matter to assume the regularity of form which crystals exhibit, it is obvious that they must have *freedom of motion.* This is usually effected by reducing the substance to be acted upon either to a gaseous or liquid state.

When a substance is reduced to a liquid state, by its solution in some appropriate menstruum, as water, alcohol, &c., its particles are considered to be disposed at regular distances in the liquid. If the quantity of liquid be considerable the particles are too far apart to attract each other, but if the quantity of the liquid be diminished by evaporation the distances diminish, and at length the particles entering within the sphere of each other's attraction are drawn together by certain laws which induce them to assume a definite form, as a cube, a rhomb, a prism, &c. Other particles remain dissolved in the liquid, forming what is called the mother liquor.

That this phenomenon may be effectually produced, it is essential, as just stated, that the particles have great freedom of motion, and whatever tends to prevent this tends likewise to check crystallisation. If the menstruum be limpid and thin, the effect is produced most favourably; but if it be

thick, adhesive, and tenacious, the reverse will occur.

The size and regularity of form in the crystals will be influenced by the rapidity of the evaporation. If this process be slowly conducted, the particles unite with great regularity; if it be hurried, the crystals are irregular and confused. We have good examples of the two cases in loaf sugar and sugar candy.

If these data be applied to the management of the syrup when skipped, such a plan should be pursued that the syrup may be preserved in a state as free as possible from viscidity or tenacity, so as to admit of the easy approximation of the saccharine particles. For this purpose the contact of cold air, and particularly draughts of wind, should be avoided; and to prevent the too sudden or rapid cooling of the syrup, it should be exposed to a gentle and uniform temperature. That the crystals of the sugar may be perfect in form, distinct, and sufficiently large, the syrup should be placed in such a condition that the process of crystallisation shall not be too hurried. It must, however, at the same time be borne in mind that the results of the operation must be regarded in a commercial rather than chemical point of view; consequently, that the time allowed for its performance should be no more than what is absolutely necessary; for in this, as in all other branches of manufacture, time is capital, and can be spared only at a certain sacrifice.

To effect these objects, the concentrated syrup

should be skipped immediately into moulds or forms, or into large wooden cases of a size sufficient to contain a hogshead of sugar. In either case these receivers should be placed in a curing house, the uniform temperature of which is carefully preserved, and from which all currents of air are excluded.

When forms or moulds are employed their size should be as great as can be given to them consistent with a facility of their being lifted and reversed when their contents are required to be taken away; because they will occupy less space, a less amount of labour will be required to discharge an equal weight of sugar, the cooling of the syrup, in consequence of its greater bulk, will proceed more slowly, consequently the crystallisation will go forward for a longer time, and will in every respect be more complete and perfect.

The moulds having the holes at their extremities plugged up with a piece of rag, are to be placed side by side over jars which rest on the *floor* of the curing-house; or they may be fixed in holes cut in tables made for the purpose, under which are gutters for carrying away the molasses as they escape. These vessels are to be filled in succession with the syrup from the teache; and when crystallisation has advanced so far as to form a crust or pellicle on the surface of the syrup, a wooden knife must be introduced, for the purpose of separating the crystals on the surface and those which adhere to the sides of the vessel, and dispersing them throughout the mass. This operation should be repeated

once or twice, otherwise the crystals which always appear first at those parts of the syrup most exposed to the cooling action of the atmosphere will drive the liquid portion to the centre of the cone. The drainage under such circumstances would be tedious and incomplete, and the lower half of the sugar likewise, from the percolation of the dark molasses through it, would be soiled. Moreover, if the cooling took place very rapidly, the crystallisation of the sugar would be replaced by the formation of compact rocky masses, which would never undergo complete drainage.

When the contents of the moulds have attained throughout the temperature of the curing-house, which will be in 24 or 36 hours, the plugs should be withdrawn, and the molasses allowed to escape.

It sometimes happens that in consequence of an insufficient concentration of the syrup the sugar in the moulds is too free, and a quantity of crystals may escape with the molasses. When this is the case, it is advisable to introduce into the hole at the apex of the mould a hollow cone of tin or copper similar in shape to an extinguisher, which is pierced with a number of small holes of such a size as to admit of the escape of the molasses, but which will retain the crystals of the sugar.

The curing-house ought to preserve a great uniformity of temperature, that of 90° being the one best suited for all purposes. This is readily effected without artificial aid within the tropics. All currents of air should be prevented, and light should be freely admitted; the windows which are

now left open should be glazed and closed, or, still better, glass sky-lights made in the roof may be advantageously substituted for them.

The refiners of Europe always employ *moulds* for potting their sugars, and in many respects they offer advantages over the kind of vessel I am about to describe, for the drainage from them is more rapid and more complete, and the sugar in consequence is more speedily and more effectually cured. They also admit of a more easy and more successful syruping afterwards, should it be desirable to submit the sugar to that operation. On the other hand, their use requires more labour, a more spacious curing-house, and I think that the crystals of the sugar are both smaller and less perfect than when the following plan is employed, which, perhaps, on the whole, at the present time is the one best suited to the colonies.

A sufficient number of water-tight wooden chests or boxes, varying in size from three to four and a half feet cube, according to the quantity of produce daily obtained, are to be placed side by side on the joists of the curing-house, in such a way as to leave between every two rows a passage or gangway for the use of the people employed in the works.

Each box should be provided with a false bottom placed about two inches above the lower one. It may be formed of a sheet of metal perforated with a great number of minute holes, of fine metallic wire or of wicker-work, and must be so strengthened as to admit of its supporting the weight of the superjacent sugar. The false bottom may be co-

vered over with a piece of coarse sacking, on which is to be spread a layer of dry sugar, about an inch in thickness. A wooden plug, a cock, or, still better, an American molasses' slide, is to be inserted into the space between the two bottoms; the apparatus is then complete.

Skip after skip of the concentrated syrup is to be poured into this vessel until it is full. Each skip as it is poured in must be blended with those which have preceded it, so as to equalise the temperature of the whole.

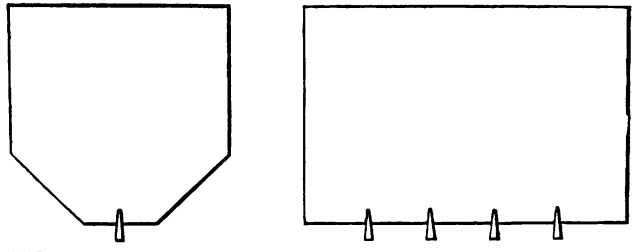
When the vessel is filled its contents must be allowed to remain in a state of repose until a film of crystals is seen upon the surface. A slight stirring will then be required to disperse the crystals, which must be repeated occasionally until all danger of the formation of a cavity in the centre is past.

So large a bulk of hot syrup necessarily requires a much longer period to cool than would be demanded by the contents of a large mould. Three or four days will, however, be quite sufficient for the purpose.

When the mass has set, has become solid, and has acquired throughout the temperature of the curing-house, the plug must be withdrawn and the molasses suffered to escape.

The form of the crystallising vessel may be modified in a variety of ways. The following may be employed with advantage. Instead of a false bottom it may have three or four holes of three quarters of an inch in diameter bored into it. These

holes should be fitted with wooden plugs, which can be withdrawn when the drainage is required to begin.



When the concentration of the syrup has been effected at a low temperature; in suchwise that crystallisation of the sugar has taken place at the same time, it is customary to skip into a heater, that is, a vessel surrounded by a steam jacket. By this means the temperature of the syrup is preserved, and very frequently augmented several degrees. It is here kept for some time, being frequently and briskly stirred, so as to mix together the different skips, to equalise their temperature, and to diffuse the crystals as much as possible.

In consequence of the regulated degree of heat to which the syrup is submitted during this process, it is presumed to be placed in a condition best suited to assist the crystallisation of that portion of it which from over saturation has a tendency to separate in a solid form, and which would do so in an amorphous or semi-crystalline state, were the temperature not kept up. While in this fluid state it is passed into the moulds, and is then treated in the manner described.

This operation is essential to the refiner, but it is questionable whether the advantages that it

offers to the planter are sufficient to compensate for the additional trouble and expense that its employment would entail.

Indeed I think the use of the heater may safely be dispensed with in those colonial boiling-houses where the syrups are concentrated at a low temperature, and one of the former plans of skipping into cold granulating vessels be substituted for it. When concentration is produced by ebullition in the open air, the employment of the heater would be inadmissible.

It is now several years since a patent was taken out by Mr. Hague for "certain improvements in the method of expelling molasses or syrup from sugar." This plan consists in placing the concentrated syrup in a vessel which has a false bottom perforated with many minute holes. When the mass is sufficiently consolidated a vacuum is formed in the space between the two bottoms, into which is inserted the suction-pipe of an air-pump for the purpose. By the pressure of the atmosphere it was imagined that the molasses would be expelled, leaving behind them the solid sugar.

The same principles are carried out in an improved manner in the pneumatic pan lately patented by Mr. Cooper.

In the granulating or curing apparatus of the latter gentleman, the concentrated syrup can be skipped directly from the teache; and when the granulation is completed, on a sufficient amount of exhaustion being effected, the resilience of the cane-work, of which the false bottom is constructed,

is overcome, and the molasses are forced away, leaving the crystallised sugar behind.

Pneumatic curing vessels, however, of whatsoever construction they may be, perform the purposes for which they are intended very inefficiently, when employed upon the badly granulated sugars made at the present time in the colonies. The attraction between the false grain of the sugar and the surrounding viscid molasses cannot in this manner be overcome; for whatever may be the degree of vacuum obtained, a large portion of the soft and yielding sugar is forced away in the drainage, and a quantity of molasses more or less considerable is still retained. But when the sugar has been manufactured in a skilful manner, when the grain is large, bold, and distinct, an apparatus of this kind, there can be little doubt, may be employed with considerable benefit in the economisation of the time at present required for the "*curing*."

CHAP. VII.

CLAYING. — LIQUORING OR SYRUPING. — HOW PERFORMED. — ITS ADVANTAGES. — ITS ACTION.

WHEN the drainage from the sugar in the moulds or chests has ceased, or when the molasses come away very slowly, it is at all times advisable to assist their more perfect separation by artificial means. The process by which this object is obtained may be said to constitute the essential part of the art of refining, as by it we have it in our power, provided the previous stages of the manufacture have been skilfully conducted, of obtaining sugar of the most perfect whiteness and purity — the only limits in this respect being the commercial consideration of profit and loss.

The means formerly employed by the refiner and beet-root sugar manufacturers of Europe for effecting this object consisted in applying to the upper surface of the sugar a "*magma*," composed of clay beaten up with water to the consistence of a thick cream. The water being in a great measure retained in the clay, as in a sponge, separates slowly from it, and percolates gently and gradually through the sugar, forcing the dark molasses before it. In the course of a few days the clay becomes dry; it is then removed, a fresh supply is administered,

and this is repeated until the sugar acquires the colour desired.

This process is still pursued in Cuba and the Brazils; but there are certain disadvantages attending it which are sufficient to cause its total abolition in every boiling-house, namely, its inefficiency for the purposes intended, the great loss of weight produced by the dissolution of the granulated sugar in the water, and the length of time required for its performance. The following system ought always to be substituted for it.

Liquoring or syruping the sugar has for its object the replacing of the dark-coloured molasses by another liquid of greater purity and of lighter colour. The liquid to be selected for this purpose must be of a sufficient density to force the molasses before it as speedily as can be done with benefit; it must be incapable of dissolving any portion of the sugar with which it comes in contact; it must be much lighter in colour than the molasses to be displaced; it must be innocuous to health, and of such a nature as not to diminish the degree of sweetness of the entire mass.

The only liquid with which we are acquainted, that possesses all these qualifications, is a light-coloured syrup, of such a density as to indicate its saturation at the temperature of the atmosphere.

When in the judgment of the sugar-boiler the contents of the moulds or cases are sufficiently cured to admit of their being liquored, he must proceed as follows. The crust which always exists on the upper surface of the sugar must be removed

to the depth of one or two inches, and an even and perfectly smooth face must be given to the sugar below by means of a curved knife and a trowel. The sugar which has been removed must be crushed fine, and mixed with cold water to the consistence of mortar, so as to form a magma, or paste, free from lumps, in which state it is to be returned, and spread over the face of the sugar as evenly as possible.

In a few hours the face of the sugar will have become again sufficiently free from moisture to allow the liquor or syrup to be poured on it.

To prepare the syrup we may employ either the refined lumps imported for the purpose, or sugar expressly prepared in the boiling-house; or, perhaps, what will in general be found most advantageous, a quantity of syrup taken from the evaporating vessel, and rendered of the density required by the addition of the necessary quantity of footings or headings.

However prepared, the syrup must have the colour which the quality of sugar we may be desirous of obtaining will demand. For this purpose, when the liquor is not prepared from refined sugar, it is essential that it should be passed through a charcoal filter, or that it shall be blown up with fine charcoal and blood, and afterwards filtered through bags.

If the syrup be prepared from sugar alone, its concentration must be carried on until it has a density of 31° 5′ Beaumé, when cold. If it be prepared from liquor from the evaporating vessel

and dense and pasty footings, its density must be about one degree higher.

When perfectly cold, the syrup must be poured to the depth of two inches over the sugar prepared in the manner just described; and it is necessary that a smooth and even face shall have been formed, otherwise the syrup is liable to percolate very unequally, and often to escape through holes and passages which it makes for itself.

In the colonies it will seldom be necessary to "syrup" more than once, but if a still better colour be required the operation may be repeated. We may, if we choose, as I have already stated, by the use of very colourless syrup, produce a sugar equal to the best crushed lumps of the European refiner. It may, however, be doubted whether carrying the process of syruping to the extent practised in Europe will be, on the whole, profitable.

Sugars which have undergone this process, even to a limited extent, are not improved in colour only, but they are also much drier, less adhesive, their grain is more distinct, and they suffer no loss of weight from leakage during the voyage home.

The process of syruping or liquoring the sugar is not merely an improvement upon the old method of claying, for the principles on which the two act are different. By the use of the clay we obtain merely the beneficial results which are caused by the washing of the crystals with water, and these are effected at a considerable loss. For the water as it percolates dissolves more or less of the sugar

with which in its passage it comes into contact; and in consequence of its union with the molasses, its bleaching effects are confined to a small distance beneath the surface. But a solution of sugar of the required density being in a state of perfect saturation cannot so act: it already contains as much sugar as it is capable of dissolving at the surrounding temperature; and its action is consequently confined to the purely mechanical one of forcing by its weight and pressure the molasses before it, and of occupying their place.

On the surface of sugar which has been syruped there is formed a hard crust of very little thickness, but which is always of a deeper colour than the sugar underneath it. This crust may be removed, or it may be bleached by covering it with a damp cloth, which acts in the same way as moist clay.

It has been recommended to use strong spirits of wine for the purpose of discharging the molasses from sugar. As this plan presents no advantages, and as it is one attended with considerable expense, it has never been generally adopted.

When the pneumatic curing pan is employed, the molasses may always be effectually discharged from the interstices of the sugar by causing a quantity of fine syrup to be forced through when the curing is sufficiently complete. But the quantity of syrup required for the purpose must be very considerable, owing to the form of the pan and the large surface of sugar which is exposed. The process, therefore, when applied under these

circumstances, will necessarily be a very expensive one.

When the sugar after it has been syruped is sufficiently dry, it must be taken out of the moulds and cases and put into hogsheads or bags ready for its shipment. Those portions, however, which still remain moist may be used for making the syrup for liquoring: they may be put into smaller vessels to undergo a renewed drainage, or, if very clammy, they may be returned into the concentrating vessel, and there be mixed with the syrup which it contains.

When practicable, some advantage would be obtained by exposing the sugar to the heat of a stove for a day or two previously to its being placed in the hogsheads, but not sufficient to repay the expense of erecting a building for the purpose.

CHAP. VIII.

CONCENTRATING THE GREEN SYRUP, OR MOLASSES.

By the mode at present pursued of potting in the hogshead, the drainage as it escapes passes directly into the molasses' cistern, a cavity situated immediately beneath the beams of the curing house. This cistern is consequently exposed and open. It is lined with cement, and is seldom in a perfect state of repair.

Here the molasses remain until they are shipped, or until they are required for distillation. The result is, as might be expected, rats, cockroaches, and other vermin, creep in and assist, by their decomposition, the rapidity and degree of the fermentation, which, under any circumstances, is sooner or later certain to arise.

In the palmy days of West India prosperity this lax and improper system may in some degree have been excusable, owing to the highly remunerative prices obtained for all the produce; at present it can only be considered as one of extravagance, and therefore of loss.

In the first place, a quantity of molasses is always lost, either in consequence of the leakage of the cistern, or from its absorption by the cement. 2. Owing to the evaporation constantly going on, a

quantity of a soft, whitish, and amorphous sugar is precipitated to the bottom of the cistern. 3. The vinous and acetous fermentation set in, and a part of the saccharine matter is converted into carbonic acid, alcohol, and acetic acid or vinegar, while another part is converted into uncrystallisable glucose. Thus from a fluid possessing a bland, sweet, and sugary taste, the molasses are often changed into one having an offensive smell and a foreign and disagreeable taste. During the voyage these changes continue, and often increase in intensity, from the high temperature existing in the hold of the ship. Nevertheless, in spite of all the injuries which they have received, the molasses, on their arrival in this country, find a market, and by the skill of the purchaser are converted into sugar, of a quality superior to that from which they were originally obtained.

Can there be a greater proof of the ruinous management of a West India sugar estate than this fact? (In Jamaica, owing to the high price obtained for the rum, the molasses are wholly converted into that spirit, and the loss is considerably diminished in consequence; but in those colonies from which molasses are exported, the decomposition which they undergo is a serious item in the depreciation of revenue of every estate.)

Many planters assert that molasses cannot be concentrated so as to afford sugar by the plant now in use. I know not how they have arrived at such a conclusion; for in the Mauritius, where the distance from a market causes the exportation of the

molasses to be an unprofitable speculation, the first and second syrups are always reboiled, and not unfrequently the third also. The plant of that island is the same as the one in use in the West Indies.

At present the West India proprietor for the most part distils one part of his molasses, the remainder is shipped to this country or to America. If it is found more beneficial to send them to an English market than to distil them on the estate, it is evident that the profit which there attends their conversion into sugar is obtained at the expense of the proprietor, who has to submit not alone to that loss, but likewise to the one which results from their deterioration, and this cannot be less than from ten to fifteen per cent., and probably it is much more.

There can be no doubt that the molasses ought to be converted either into rum or sugar on the spot where they are produced, and at as short a time after their separation from the sugar as possible. The first may not be a remunerative operation ; but either the second must be, or else the manufacture of sugar from cane-juice is one altogether profitless. For while the expenses attendant on the cultivation of the canes, and the concentration of the juice into sugar, are considerable, those required for the boiling of the molasses are very small indeed, the amount of evaporation necessary for their inspissation seldom exceeding twenty per cent.

Were the concentration of the green syrup or

molasses generally practised, the economy that would result would not be confined to the increase in the quantity of sugar that would be obtained; but the adoption of the plan would also admit of a considerable improvement in its quality. It is now the object of the planter to extract at one operation from the cane-juice as great a quantity of sugar as he can, the consequence is, that the point of concentration is often carried too far. This appears to have been the case whenever the method of concentrating *in vacuo* has been pursued; and although the crystallisation is in those cases generally very perfect, the separation of the molasses from the sugar is rarely found to be complete, and the value of the latter article is thereby rendered less than what it would otherwise have been.

If the conversion of the molasses into sugar be decided upon, every means ought to be adopted to perform the operation before their fermentation shall have commenced. Instead, therefore, of allowing the drainage to pass into an open cistern, the syrup should be collected in gutters, made of tin or wood, placed for the purpose underneath the crystallising vessels, and by this means be conveyed into clean puncheons so fixed as to receive it.

At the end of the week, at the latest, the molasses should be worked off. This may easily be done; as Saturday, a day on which no work is performed in the greater number of the colonies, may be set apart for the purpose.

Molasses, like the original syrup, may be concentrated either over the naked fire or by steam, at a

high or low temperature; and the same directions are applicable to them as were before given for the cane-syrup. We should remember, however, that the poorer the syrup the more stiffly will it require to be concentrated; so that if the syrup which drains from the molasses-sugar be reconcentrated, it should be inspissated as highly as is consistent with its ultimate drainage.

The more stiffly these low syrups are concentrated the greater will be the temperature required for curing the sugar produced from them.

After every consecutive concentration the molasses acquire an increased density. When it becomes equal to 44° Beaumé, crystallisation can no longer be induced.

The drainage which comes away from the first sugar after syruping should be carefully separated from the molasses themselves: it should be returned to the evaporating vessel, and there be mixed with the defecated cane-juice. The drainage from the molasses-sugars or bastards, when syruped, may be mixed with the first quality of the molasses, or it may be thrown into the concentrating vessel at once.

The sugar obtained from the first molasses ought always to be liquored, and the syrup used for the purpose should be made from the sugar obtained from the cane juice.

Concentrated molasses are sometimes too poor to bear much stirring in the crystallising vessel.

The time required for their crystallisation is in proportion to their richness, and may vary from

twenty-four hours to a week. The drainage should not be suffered to commence until the necessary quantity of grain is fully formed.

It is by producing a superior quality of molasses that one very considerable advantage is obtained by the filtration of the evaporated cane-juice through animal charcoal. When this process has been pursued, the molasses may be concentrated without undergoing any previous treatment. When it has not been resorted to the molasses have a darker colour, and they are more viscid and tenacious, nevertheless they may likewise be reboiled or otherwise concentrated at once, and the sugar produced will be of a tolerably good quality.

But in England molasses are either blown up with fine charcoal and blood, or with alumina: they are then passed through bag filters, and afterwards through deep beds of animal charcoal. In the colonies the filtration through charcoal would be far from economical, as the force of the charcoal would be expended on bleaching a liquid, a portion of which, after the extraction of a profitable quantity of sugar, is destined merely for distillation.

Dark and viscid molasses are much improved by being blown up with a little sulphate of alumina and chalk or lime, in the manner described in the chapter on Defecation. When this is performed, they should be reduced by the addition of a small quantity of water to the density of 32°, 33° Beaumé; and after ebullition in a *copper* vessel, be passed through bag filters. This operation will not be

urgently required if the molasses be submitted to concentration at as short a period as possible after their separation, and before fermentation has commenced. The results produced by it are, however, always beneficial.

When the last drainage from molasses-sugar becomes at length so poor, as in the judgment of the planter to be unfit for a profitable concentration, it should be conveyed to the still-house to be converted into rum.

The number of times that the molasses may be submitted to concentration will depend upon many circumstances: in the West Indies, twice probably will be the utmost that this operation will be performed, even when the cane-juice is rich: the third runnings in all cases will, there can be little doubt, be most advantageously used for distillation.

When the syrup shows no sign of granulating, this result may often be obtained by stirring through it a small quantity of dry sugar to form nuclei for the crystals.

For the perfect curing of sugars obtained from low syrups, the temperature of the curing-house should be at least 100°, when that point can be obtained without inconvenience; and the air should be as free from moisture as possible.

CHAP. IX.

RECAPITULATION. — ALTERATIONS REQUIRED IN PRESENT PLANT. — ERECTION OF NEW BOILING-HOUSES, ETC.

WE have now gone through all the operations which collectively form the manufacture of sugar from cane-juice. It has been shown that each of them possesses an evident and distinct purpose, on the attainment of which the successful result of the whole will greatly depend. The principles on which their right performance is based have been explained, and the application of those principles has, I hope, been proved to be both easy and simple. My reward will be great, could I be assured that the reader, if he be a planter, will rise from the perusal of the foregoing pages with clearer views than he before had of the theory of his art; that he will have acquired the conviction that it possesses none of those mysterious difficulties with which his imagination has too frequently clothed it, and that he will thereby be encouraged to practise it with pleasure to himself, and with profit to his employers.

Let us again take a short and retrospective view of these operations, the better to impress upon the memory the objects which by their means we wish to obtain.

1. The canes should be cultivated with a view not merely to their size and abundance, but we should, at the same time, by every means in our power, cause them to yield a juice as rich in saccharine matter and as free from all impurities as possible; and to prevent the evil which would result from decomposition of the juice, when cut, the canes should be conveyed to the mill without loss of time.

2. We should attempt to get from the canes the largest quantity of juice, either by improved mills, or by close attention to the fitting, bracing, feeding, &c. of those now in use; by sprinkling the megrass with water, or by exposing it to steam, and by repassing it between the rollers.

3. We must employ the best means in our power to defecate the cane-juice, that is, to make this liquid approximate as near as we can to a solution of sugar and water only. Its speedy exposure to the action of a high temperature must be effected, and the greatest caution must be practised in the administration of the "*temper-lime.*"

4. The defecated liquor should be evaporated to the density of 32° Beaumé, or to any other suitable degree, with the greatest expedition; care being taken at the same time that the carbonisation of even the smallest particle of the sugar be prevented, by constantly preserving in the pan a depth of liquor sufficient to cover that part of it which is exposed to the fire.

5. The object of filtering the liquor through animal charcoal is the more perfect removal from

it of the albuminous principles, excess of lime, colouring matter, acidity, &c.

6. That the concentration of the syrup to sugar proof should be effected with rapidity, and at the lowest temperature possible.

7. That to promote an abundant and perfect crystallisation, repose, moderate warmth, and an equable temperature are necessary; and to effect the better curing of the sugar, these two operations should be performed in the same vessel.

8. That to induce the complete separation of the molasses, the sugar, when sufficiently cured, should be submitted to the process of liquoring.

9. The molasses must be concentrated before any fermentative change shall have commenced.

Such are the objects that the planter has in view (whatever may be the means selected for obtaining them) in his efforts to extract sugar from the sugar-cane. In my humble opinion at least, a knowledge of the principles on which those operations are based will be found to benefit him far more than the supply of the most expensive machinery and apparatus where this knowledge is wanting. It is not the instrument that makes the musician, neither does it follow that the most perfectly arranged boiling-house will produce the best sugar, where the skill which ought to direct its management is wanting.

A sugar boiler who understands his business will always be able to accomodate his means to his purposes.

A little reflection will show that all the foregoing operations may be performed, more or less satis-

factorily, in a variety of ways; that is, by keeping in view the objects sought for, the merely mechanical contrivances introduced to effect them may be modified almost infinitely. We have sufficient examples of these contrivances in the great number of patents which, within the last few years, have been obtained in this country and in France for improving the manufacture of sugar, and in the various and costly machinery lately introduced into some of our own as well as into several foreign possessions. In not any two cases, probably, is the plant exactly alike. On one estate the evaporation is performed over the fire, on another by means of steam, while in the central factory of Guadaloupe this process, as well as the subsequent one of concentration, is conducted *in vacuo*.

It must not be supposed that I undervalue the importance of those inventions: on the contrary, I consider them as improvements in the highest degree, and as such deserving the greatest commendation; but it cannot be denied that the results which have followed their precocious introduction into the colonies have generally indicated that both proprietors and planters have commenced at the wrong end; that they have sought perfection without having previously acquired the knowledge necessary to attain it. Moreover, the vast majority of estates are so encumbered, and capitalists have yet so little confidence in the results of free negro labour, as to preclude, for the present at least, the possibility of their possessing generally new and expensive apparatus; I must therefore reiterate my

conviction, that the great element of success in the planter is such a knowledge of his business as will enable him to improve the circumstances which surround him.

I have already pointed out a method, unaccompanied with expense, of improving the present arrangement of the boiling-house. I shall now proceed to mention one or two others.

Let us suppose that a planter has to conduct the management of an estate, on which the boiling-house contains, for manufacturing purposes, merely five old-fashioned teaches constructed of iron; that there shall be a great deficiency of available means, and that poverty admits only of the least expensive improvement in the plant. Much even here may be done: an increase in the quantity of juice obtained from the canes, equal to from five to ten per cent. over that previously expressed, will in all probability be effected by the bestowal of a little care and attention upon the mill. The removal of the teache, and the substitution for it of a circular flat-bottomed concentrating vessel, made of copper, and set upon a separate fire, will be required. The remaining pans will continue *in situ*, the fire being applied underneath the one which before was the second, but which in the new arrangement will be the first. A set of bag-filters, fitted as near as possible to the first pan, that is, in the place previously occupied by the teache, completes the alterations. The cane-juice on being received in the grand copper is exposed to the action of heat and lime, that the separation of the nitrogenised substances may be as complete as pos-

sible. If the pans be made of iron, the defecation cannot be assisted by the addition of a little sulphate of alumina, in consequence of the action which the sulphuric acid would exert upon that metal; the hydrate of alumina produced by the decomposition of the sulphate should therefore be substituted.

The scum should be removed in the usual manner; and when the liquor in the vessel which is placed over the fire acquires the density of 32°, it should be passed into the bag-filters. After filtration the syrup is to be concentrated, and the sugar should be crystallised in boxes of a size suited to the work to be performed.

By this mode of treatment the amount of crystallised extract will be much greater, and its quality will be superior to that obtained when the ordinary method of manufacture is pursued.

Should we be desirous of effecting a still greater improvement in the quality of the sugar, a quantity of fine animal charcoal may be thrown into the liquor when duly skimmed and defecated, in the proportion of from five to six pounds of the former to one hundred gallons of the latter; and when the liquor in the first copper has acquired the density of 30°, two pounds of dried blood, previously dissolved in five or six gallons of cold liquor, are to be thrown in and briskly stirred; ebullition will recommence almost immediately, when the whole should be skipped into the bag-filters. When the pans are made of copper, the defecation may be rendered more effectual by decomposing

the sulphate of alumina while in contact with the cane-juice by the addition of lime or chalk.

To assist as much as possible the work of the filters, sieves, constructed with metallic wire, may be suspended over each copper, and the liquor in its progress forward should be caused to pass through them. The meshes of course should be as small as is compatible with the rapid transmission of the liquor.

Another modification in the arrangement of the plant consists in retaining all the coppers as they now are, but confining their use to defecation and evaporation merely. The cane-juice after defecation and the removal of the scum is to be evaporated to 33°, and on its attaining that density it is to be conveyed from the teache to a large clarifying vessel, made deeper than those which are usually so called, and capable of holding three or more skips. To each skip as it enters should be added a quantity of fine animal charcoal, and when the vessel is sufficiently charged, blood, either fresh or dried, must be thrown in. Heat must then be applied, and when ebullition has fairly commenced, the fire is to be damped and the liquor must be run into the filters.

If the merits of Gadesden's concentrating pan be found on experience to correspond with the reports now received respecting it, this apparatus ought to replace the open vessel, in which concentration can only be effected at a high temperature, whenever the means of the proprietor will admit.

Slight alterations in the plant, similar to the above, are, I am afraid, the only improvements that the poverty of many proprietors of sugar estates will admit of being effected in the boiling-house, at least for the present.

Were the sugar colonies in a more prosperous condition, so as to encourage the formation of new establishments for increasing the production of their staple, the following considerations should direct us in the choice of locality and the mode of erection: — 1. The obtaining of a cheap motive power. 2. The easy supply of fuel other than megass. 3. The facile communication with a good shipping place. 4. The economical and effective arrangement of the plant. Let us apply these desiderata to the construction of a boiling-house capable of making 300 tons of sugar.

Of all motive powers, none can be compared with water in point of economy, nor is any more effective when the supply is permanent, abundant, and skilfully applied. Its mode of application should be that of an overshot wheel.

The mill should be of the most solid and artistic construction, and should be composed of four rollers. It ought to be sufficiently elevated to permit of a gentle descent in the passage of the cane-juice into the clarifiers. Those vessels should be three in number, and they may either be square to economise space, or altogether of the form and size of those now in use: their contents may be heated with dried cane-tops or megass, and ebulli-

tion of their contents must be induced as quickly as possible.

The clarifiers should likewise be so raised above the level of the evaporating vessels as to permit the defecated and filtered cane-juice to run from the lower cistern of the filters directly into those vessels without the assistance of a pump or *monte-jus*.

The evaporating vessel or vessels should be constructed on the plan of either of those recommended in the chapter on that subject; and to its discharging extremity there should be attached a cylindrical copper cistern, resting on the floor of the boiling-house, and rising to a level with the bottom of the evaporator. The cistern should be closed at top, and it should communicate with the evaporator by means of a pipe on which is fixed a stop-cock.

In it also is to be introduced the whole of the working barrel of a small force-pump, for the purpose of raising the syrup either into the charcoal cisterns, when they are used, or into the cistern from which the concentrating vessel is to be supplied. The evaporation should be effected by coals.

The objection raised against the use of pumps is the liability to souring of the liquor induced by the decomposition of a small quantity which is absorbed by the wood, leather, and tow of the clack valve, bucket, &c. This is entirely obviated in the pump patented three or four years ago by Messrs. Palmer and Perkins, which is composed entirely of metal, the valves being merely elliptical disks of copper. These pumps also are worked with the greatest facility, the friction being reduced almost to a nullity.

For the purpose in question it is impossible to recommend this kind of pump too strongly; for by its use we have all the advantages of a hot or cold *monte-jus* in a boiling-house, where, from the absence of steam, the latter is inapplicable.

When a pump is employed to raise boiling liquids it may perhaps be necessary to mention that the working barrel should be immersed in the fluid to be raised.

The modes of filtration through charcoal have been described.

As the employment of steam is not contemplated in a boiling-house constructed upon this plan, the choice of a vessel for concentrating the syrup is limited to one of those in which this kind of heating medium is not required.

There are few situations which possess all the above advantages for the establishment of a sugar factory: one or more of them will generally be absent. For instance: we not unfrequently see that, for the purposes of getting a good water power, other considerations have been entirely overlooked at the time when many estates were established. This is more frequently observed in those islands which have offered great advantages in this respect. Water is an excellent and cheap power, which should always be taken advantage of when the other requisites are present at the same time; but it is one which we should not hesitate to sacrifice when they are absent.

Steam is a motive power, by the employment of which we almost always have it in our power to

select a situation for the erection of sugar works which will possess all the other advantages; for which reason there can be little doubt this agent will be the one hereafter most generally adopted.

When steam is the motive power employed in a sugar factory newly established, it may also be the agent selected for the production of heat, should it be thought necessary.

The engravings at the end of the volume, after the design of Mr. Harthill, will enable the reader to understand more fully than any written description could do, the plan and arrangement to be followed in the construction of two boiling-houses, capable of working off 500 and 1000 tons of sugar respectively in five months.

CHAP. X.

CONCLUSION. — QUANTITY OF SUGAR CONTAINED IN SUGAR-CANES. — LOSS SUSTAINED FROM THE MEANS NOW EMPLOYED IN THE MANUFACTURE OF SUGAR. — REMEDIES PROPOSED. — LABOUR. — CENTRAL FACTORIES. — IMPORTATION OF CANE-JUICE IN STATE OF A CONCRETE. — MODEL FARMS AND FACTORIES. — AGRICULTURAL SOCIETIES.

IT has at all times been known to the planter that the losses sustained in one way or other in the manufacture of sugar have been considerable; but the sources of those losses, and their real amount, were, until lately, subjects on which a very general ignorance prevailed. The extensive researches which have of late been made in organic chemistry, and the application of this department of science to the manufacture of sugar, as well as to other branches of art which have required its assistance, have given us much clearer views on both these points than we formerly had; and we are now able to arrive at the most accurate conclusions respecting the amount of losses sustained, as well as furnished with the means, if we choose to avail ourselves of them, of discovering the causes which produce them.

It has been ascertained, by experiments so numerous and so varied as not to admit of a doubt respecting the accuracy of the results obtained by them, that the stem of the sugar-cane consists

essentially of two elementary portions or divisions, the one being the woody fabric or skeleton of the plant, the other the fluid contained within it; and that the relative proportions which the two bear to each other may be stated in round numbers to be ten parts in weight of the former, and ninety parts in weight of the latter in every one hundred.

It has likewise been ascertained that while the proportions between these two parts of the plant preserve a great degree of uniformity, there is often found a considerable difference existing in the quantities of the respective constituents of the latter or fluid portion; which constituents consist of sugar, salts, nitrogenised proximate vegetable principles, and deliquescent matter, held in solution in a large amount of water.

It has also been ascertained, that the combined quantities of all these bodies contained in a given amount of cane-juice bears a tolerably close ratio to the specific gravity of that fluid; and also, that as the proportion of the other substances is always small compared with that of the sugar, the density of the cane-juice is for all practical purposes a good indication of the amount of the latter, which it contains.

It has further been ascertained, that whatever may be the amount of saccharine matter contained in cane-juice, it is invariably of that kind known as crystallisable or cane-sugar; and that, if by the term molasses be meant a fluid containing any other variety of sugar than the above, such a substance does not exist in the cane-juice.

The molasses are always to be considered as a result of the manipulations to which the cane-juice has been submitted, so that when that liquid has been judiciously treated, the molasses which have been obtained constitute merely the mother liquor resulting from the crystallisation of a portion of the sugar, they must, therefore, be composed of the other portion of the sugar, and the before-mentioned components of the cane-juice which have not been separated by defecation, in a state of solution in water; but when, on the other hand, the manufacturing processes have been improperly performed, the molasses will be found to contain other matters likewise which have been produced by changes induced in the sugar, as glucose, mannite, gum, the glucates and melasinates of lime, &c. The latter is generally the case in the common molasses of the market.

Cane-juice having a specific gravity of 1073, or 10° Beaumé, at a temperature of 60°, contains 18 per cent. of solid matter, of which 18, minus about $\frac{7}{1000}$ is sugar. At a temperature of 80° the same amount of sugar would be indicated by a density somewhat below the above; and it may be safely stated without exaggeration, that at the degree of heat common to tropical countries, cane-juice of this density contains fully 18 per cent. of pure sugar.

Experiments performed for the purpose have proved over and over again the truth of the above statements. They have further shown that the density of cane-juice during crop is generally higher than the one given, and that the quantity of sugar

contained in that fluid not unfrequently exceeds 22 per cent. For the purpose I now have in view, however, I shall take the average density of cane-juice at 10° Beaumé, and the amount of its sugar at 18 per cent.; and as the old wine gallon is the measure still in use in the colonies, I shall retain it in the following calculations.

From the foregoing data it follows that 3000 gallons of cane-juice of the density of 10° Beaumé weigh 25,752 lbs., and that they ought to yield 4635 lbs. of dry saccharine extract. This is not to be considered merely as a theoretical formula, or as a result which can be obtained only in the laboratory of the chemist; it is one which can likewise be produced on a large scale, and in every well-arranged boiling-house. It is true, indeed, that the extract which will be produced in the latter case will not consist entirely of crystallised sugar, for the small portion which will remain when the operation is terminated will form, in consequence of its combination with a disproportionately large quantity of saline matter, a crumbling mass that rapidly deliquesces on exposure to the atmosphere. Nevertheless, the whole of the contained sugar will be procured. Any one may satisfy himself that this is practicable if he choose to take the trouble. The experiment will be most conveniently performed at a low temperature, as *in vacuo;* but this plan is not essential, and sufficiently complete results may be obtained by evaporation and concentration in appropriate vessels over the naked fire and in the open air. After

defecation the cane-juice is to be concentrated to the point that indicates its saturation when boiling; the syrup should remain in a state of repose until crystallisation is completed. The mother liquor, when separated, should be concentrated to the same point, and the operation is to be repeated until the extract obtained will no longer crystallise; the latter must be dried at a gentle heat, and then the whole must be weighed. The amount will be equal to that indicated by the density of the cane-juice. The quantity of dry uncrystallisable extract will be found to vary at different times, owing to the purity of the cane-juice and its freeness from saline matter; but, generally, if the experiment be successfully performed it will not exceed five parts in one hundred of the whole.

I do not mention this experiment as a system of manufacture to be followed in the boiling-house, indeed the difficulties attending its complete performance during the height of crop would be too great, and the benefits that would be derived would not be sufficiently remunerative; I mention it only as a means by which a planter may satisfy himself that the results mentioned above are true, and that they may be obtained on a large scale were it necessary. I have produced in the way of manufacture, from cane-juice of a specific gravity of 1073, one pound four ounces of beautifully crystallised sugar, and three ounces of dry uncrystallised extract, from every wine gallon, which is rather more than 17 per cent.

If the statement made in the foregoing part of the book, that the average quantity of cane-juice expressed by the mills in the different colonies, does not exceed 50 per cent. of the weight of the canes be true, it is evident that the quantity of canes which now yield 3000 gallons of juice, contain in fact 5400, and that, *cæteris paribus*, the amount of saccharine extract that they ought to produce should be 8343 lbs. instead of 4635 lbs.

Let it be assumed also that the weight of the *stems* of canes grown upon one acre of land is 30 tons, or 67,200 lbs., the quantity of juice (if it be of the above density) which they contain is 7065 wine gallons, or 60,480 lbs.; and the amount of saccharine extract 10,886 lbs., or $4\frac{86}{100}$ tons.

I do not suppose that by any method yet known this result could be obtained on a large scale, and in the way of manufacture; I give the calculation only as a standard whereby we may compare the one at present produced, and thus be able to see the losses sustained. The portion of the loss alone which is not remediable by care and good management is the one that depends upon our imperfect means of expressing the juice. But who is hardy enough to say that such will always be the case? Can no means be invented by which the loss that arises from this cause may be prevented? We should possess a remedy at once were it satisfactorily proved that the process of M. Michiel could perform what it promises.

I have stated that by paying attention to the

mill, the quantity of cane-juice may be increased from 50, the present amount, to 70 per cent.; in which case the juice produced from 30 tons of canes would be 47,040 lbs., and the amount of dry saccharine extract 8467 lbs., or 3 $\frac{78}{100}$ tons; which, when the cane-juice has a density of 10°, is the one which can always be obtained by the means we now possess.

When we extend our inquiries into the results actually obtained in the colonies, such difficulties present themselves, owing to the want of data, as to prevent our forming an opinion with any thing approaching to accuracy. We know indeed that a considerable loss is sustained in every case; we know, in a great measure, the causes on which the loss depends; but of the proportionate extent in which each cause separately acts in the production of the entire loss we are wholly ignorant. So unsatisfactory is our knowledge respecting colonial statistics, that the only conclusions that can be arrived at of the capabilities of a sugar estate, or the work performed upon it, are those which are founded upon the gross amount of its produce; and this, set against its current expenses, shows the profit or loss for the year — the only question of this kind which has yet been solved.

We will, however, apply the little knowledge we possess on this truly important subject to two widely different and extreme cases.

Accounts recently received from British Guiana state, that at the beginning of the present crop 3000 gallons of cane-juice were required to make a hogshead of sugar. The hogshead, on its arrival

in England, weighed 15 cwt., or 1680 lbs. net. It is probable, but not stated, that the quantity of molasses drained from the sugar was about 12 cwt., which — 33 per cent. of water contained — gives 900 lbs. as their weight when dry; consequently the entire amount of dry saccharine extract available for the market was 2580 lbs. Let us suppose that the quantity of juice expressed was, as in the former cases, 50 per cent., and that an acre of land yielded 30 tons of canes, the quantity of juice obtained from them, therefore, would be 33,600 lbs., and that of dry extract could not exceed 3500 lbs.

In Barbadoes it is not uncommon to see an acre of canes produce three hogsheads of sugar of 15 cwt. net, and a proportionate quantity of molasses. We will again suppose, in this case as in the others, that the weight of the canes was 30 tons, and the yield of the juice 50 per cent., the quantity of juice would be 33,600 lbs.; which gave 5040 lbs. of sugar, and three puncheons of molasses — $\frac{33}{100}$ water = 2240 lbs. dry molasses; or a total of 7280 lbs. of dry saccharine extract.

The following table will enable us to compare, at one view, these different results: — No. 1. gives the products of 30 tons of canes, presuming the density of the cane-juice to be 10°; that the whole of it has been expressed, and that the manufacture has been judiciously conducted. No. 2. gives the products of an equal weight of canes: the density of the cane-juice 10°, the quantity expressed 70 per cent., and the manufacture properly performed. No. 3. shows the products presumed to have been obtained

in British Guiana at the commencement of the present crop from a similar weight of canes; and No. 4. shows the products obtained from an acre of canes in Barbadoes, the weight of which is likewise presumed to be 30 tons:—

	Weight of Canes.	Weight of Juice.	Weight of Extract.	Amount of Extract per 100 lbs. of Juice.	Amount of Extract per 100 lbs. of Canes.
1.	30 tons.	60480 lbs.	10886 lbs.	18	16·20
2.	30 tons.	47040 lbs.	8467 lbs.	18	12·6
3.	30 tons.	33600 lbs.	3500 lbs.	10	5
4.	30 tons.	33600 lbs.	7280 lbs.	21·6	10·8

Although the data which have formed the basis for the calculations in the two last lines of the table are as incomplete as they well can be, yet if we confine ourselves simply to the inspection of the different amounts obtained of saleable extract, and of these at least we have sufficient evidence, we cannot but express our astonishment.

The great excess in products which the Barbadoes estate shows over the one in British Guiana cannot, I think it will be admitted, be attributed to any superiority that the old-fashioned vertical windmill in use in the former colony has over the well-constructed steam-mill of the latter; neither can it be attributed to the greater weight of the canes, for it is not probable, if we are to judge from their size, that the weight of the canes taken from an

acre of land in Barbadoes exceeds 30 tons. It cannot be accounted for by the presumption that the Barbadoes sugar-boiler surpasses in skill his brethren of Guiana; for if this were the case, and there is no reason for supposing so, the quality rather than the quantity of sugar would be affected, as in both colonies the same system of manufacture is in force. It may be that many causes which we, from want of accurate information, may not be able duly to appreciate, have been in operation perhaps in both instances, tending either towards good or towards evil in the results produced by them; and we are compelled to believe that the predominant one will be found in the cane-juice — in its richness in the one case, in its poverty in the other. If this cause be a true one, the specific gravity of the cane-juice of the Barbadoes estate must have been as high as 1090—1095, or 12° to 13° Beaumé; while in that of Guiana it could not have exceeded 1040, or 5° to 6° Beaumé.

It therefore follows that in the latter case, presuming the above supposition correct, the cause of loss would be attributable to the injudicious custom which, unfortunately, too generally obtains throughout the West India colonies, of cutting the canes without regard to their fitness for the purposes for which they are destined.

It has been explained, I trust in a sufficiently intelligible manner, that during the rapid vegetation of the cane, the saccharine matter is re-absorbed from the cells almost as rapidly as it is deposited in them, and is employed for the purposes of nourish-

ing the plant, and affording materials for the formation of its new parts. To cut the canes when in such a condition indicates either ignorance or carelessness on the part of the person so doing, for the result must necessarily be extremely prejudicial, if we regard it only in the light of an economical management of the property. It is evident that under such circumstances the extract obtained may be diminished one half, while the evaporation required, and consequently the quantity of fuel, will be in like proportion increased. For instance, let it be supposed that the cane-juice is so rich in its saccharine constituents as to produce 1500 lbs. of crystalline extract, and 500 lbs. of molasses from 1000 gallons, the amount of evaporation to be effected would be about 800 gallons. Whereas, were the cane-juice of a quality similar to that described in the Guiana estate, that is, were it so poor as to yield only the above amount of extract from 3000 gallons, the evaporation demanded must be equal to 2800 gallons, and the quantity of fuel necessary to effect it must be $3\frac{1}{2}$ times greater than in the former case. But the money loss sustained would not be confined to the deficiency of extract obtained, or its inferiority in quality; but it would extend through all the operations of cultivation likewise.

Another source of loss, and one which has been ascertained with tolerable accuracy, although I believe that it has been on the whole undervalued, is that which results from the leakage of the sugar on shipboard. It would appear from the evidence

which we possess respecting it to vary from 10 to 15 per cent., the average being about 12½ per cent. — in money-value equal to the price of the freight. The loss thus arising is owing to the deliquescent nature of the sugar itself, which depends partly upon the retention of a small quantity of saline matter, partly upon unskilful manufacture, but generally upon the simultaneous action of both causes.

The other causes of loss sustained by the greater number of sugar plantations which have hitherto been ascertained, I have already alluded to, a recapitulation of the whole may, however, be useful. 1. Injudicious cultivation of the canes; 2. the commencement and continuation of the crop when the canes are unsuited to the purposes of manufacture; 3. the imperfect expression of the juice; 4. unskilful manufacture; 5. leakage on shipboard.

The loss produced by each of these causes respectively no doubt varies in every instance, and we have no means by which we can ascertain its amount with accuracy; but the average loss which arises from the action of them all conjointly may without exaggeration be calculated at cent. per cent.; it is often, indeed, as the preceding table shows, very much more.

These causes, it is true, are in general operation throughout all the sugar-growing countries, and therefore the depressed condition of our colonies cannot be attributed exclusively to their existence. But a due consideration of them would suggest the means of counteracting many of the difficulties

incident to the present transition state of West India property.

The first step to be taken for the remedying of an evil, is a close investigation of it, so that we may thereby arrive at a knowledge of its nature. How little in this respect has hitherto been done! It is a subject of such vast importance to the well-doing of our sugar-producing colonies, that every available means should be adopted, with as little delay as possible, for throwing upon it the fullest and clearest light. Every estate should possess a book in which should be inserted the chemical character of the soil, the mode of cultivation pursued, the nature and quantity of manure employed, the weight of canes produced per acre, their description, whether plants, rattoons, age, &c., the quantity of juice expressed by the mill, the density of that fluid and its other peculiarities, if it have any, the amount of sugar and molasses obtained, &c. &c.

I do not suppose that such a measure could be carried out at once, it ought, however, to be commenced immediately, although it be but partially so; neither do I suppose that the whole of the canes are to be weighed as they come to the mill, and the whole of their juice to be measured; but I mean that samples taken from the different cane fields should be submitted to these trials as frequently as circumstances will permit, so that both the manager and the proprietor may be possessed of information approaching to accuracy respecting matters in which they are so deeply concerned, and

in the knowledge of which they are at present lamentably deficient.

The colonial planter will probably answer this proposal by a statement that the labour which he has at his command is inadequate to the calls at present made upon it. He may, moreover, in answer an appeal made to him with a view to encourage any attempt at the amelioration of his art, (if it is to be accompanied by the sinking of additional capital, however small,) say, that in the state in which he finds himself he can scarcely pay the current expenses of his property, and that until he can feel assured of sufficient labour for every purpose of his cultivation and manufacture on reasonable terms, he can neither have courage, nor inspire those who have the ability to assist him with confidence, to undertake the outlay of capital which, like much of that which is already invested, may prove fruitless.

Without questioning the justness of these views, for it is evident that confidence in the result must be the basis of every investment of capital, it may yet be doubted whether, on the one hand, too much stress has not sometimes been laid upon the admitted deficiency of labour, and on the other, too little consideration has been given to the possibility of finding a remedy in the adoption of better modes of culture, and of improvements in the manufacture of sugar, which are demonstrated to be attainable. There is at least a great variety in the circumstances of the several colonies. In most of them it is perfectly practicable to supersede manual labour

to a great extent by the use of the plough and other implements employed in Europe. This change has indeed already made considerable progress; but any hesitation or delay in adopting so obvious a means of economy is quite inexcusable. Wherever this substitution can be effected, and it is nevertheless neglected, there can of course be no ground on which to rest any argument from a deficiency of labour. In some of the colonies, however, it is not every where practicable, and one of the most important — British Guiana — is from the nature of the country at present wholly dependent upon manual labour.

Of all the West India colonies, the last mentioned has probably been the most forward in pursuing judicious attempts at improvement. A gentleman of the highest scientific attainments has been engaged as agricultural chemist. His first report on thorough drainage has just reached this country, which, for the mass of valuable information contained in it is alike creditable to the perseverance and talents of the author and the good sense of the inhabitants. Therein is shown the injurious results produced in the staple manufacture owing to the imperfect system of drainage at present pursued — the impossibility of using the plough or horse hoe in the cultivation of the soil, the loss in the quantity of sugar obtained, estimated at one ton per acre, and its inferiority in quality owing to the superabundance of salt in the soil. A small patch of land has been appropriated by the colony for testing the improved results expected to be effected

scheme have made to the public for its support that I have seen, there are analogies instituted which are at best but suppositions. For instance, there is a presumption, to a certain extent at least, that a similitude exists between the West India colonies and Great Britain, so that what might be considered as applicable to the one country is equally so to the other. The planter and the farmer are regarded as synonymous, differing merely in the localities in which they are placed, and the nature of the crops that each cultivates. The erection of the factories is compared to the establishment of a corn mill in a district in which every farmer was previously forced to grind his own corn. We are told that the experiment is not a new one in the West Indies, because it has been tried in the East.

These are a few among several other propositions recommendatory of the different projects which have been publicly brought forward. To those who are conversant with the West Indian colonies I scarcely need to show how erroneous they are; but for the purpose of arriving at a careful solution of the first question proposed for examination, namely, the general benefit which those countries are to derive from the establishment of central factories, a closer examination of the details of the measure is necessary.

In the first place, it is essential that each factory shall be situated in the centre of the required number of plantations, which must be not only contiguous to each other, but likewise every one of them must be situated within such a distance of

the works as to render the transport of the canes as easy and inexpensive as possible. In the greater number of those islands the estates are separated from each other not merely by distance, but by lofty and steep mountains of volcanic or primitive formation, by rapid rivers subject to frequent overflows, and by valleys or precipitous ravines. From these causes difficulties are often presented in the formation of good carriage-roads that would appal the most adventurous engineer. The roads, were they constructed, would require to be kept in repair, and this must be done in a country where the rains of one season would render them again impassable. Who could possibly contemplate the erection of a central factory under such circumstances?

Unfortunately for the planter, the analogy between him and the European farmer is an ideal one only. The crops of the latter, when taken off the land, have already assumed a marketable form; they do not, as is stated, require the operations of the miller to render them so. The business of the miller has been created by the demands of the consumer, and not by those of the farmer, who has the power of exercising a choice as his interest may dictate of taking his wheat to the market or of storing it in his barn for some future occasion. But the crop of the planter becomes rapidly unprofitable and worthless unless it be manufactured into sugar immediately after it is reaped. It is very heavy and bulky, and therefore of difficult and expensive carriage, while its value is small

compared with that of the extract obtained from it. The carriage of the canes to the mill is already one of the most expensive items in the annual disbursements of an estate of moderate extent, and when the distance to be performed is small — what would it be were that distance doubled or trebled?

The canes ought to be cut when in a state of maturity. It will happen that they will arrive at this state about the same time on each of the plantations which may be connected with the factory. Will not the struggles of the different proprietors for precedence cause heartburnings, dissatisfaction, and discontent?

Nothing further need be stated to show that this scheme will not confer *general* benefit to the West India proprietors. The establishment of the factories *generally* would, indeed, be impracticable.

2. *Will their partial establishment prove beneficial to those estates which will be able to take advantage of them?* — There are in almost all those colonies certain districts where estates are situated in close approximation to each other, and where no such physical obstacles to the construction of ordinary carriage-roads, tram-roads, or rail-roads exist. Whether the establishment of factories in such places would prove beneficial to the surrounding estates is a question which it is obvious resolves itself in one of pounds, shillings, and pence.

That the planter may decide upon accepting or rejecting any assumed benefits which may be held out to him, it is necessary that he should be acquainted with their nature as well as with the

equivalent which he must give in return. That the benefits shall be real and substantial, they must consist in giving him either a more valuable product than the one he now obtains at the same cost, or in giving him one equal in value to that which he at present gets at a diminished cost. In no prospectus that I have seen are the advantages offered, or the equivalent expected in return for them, explicitly stated. At the factory at Guadaloupe the planter receives 6 lbs. of crystallised extract for every 100 lbs. of canes. And as it has been proposed by the promoters of a similar scheme in this country to return for the canes as much sugar as they could be made to yield by the ordinary method of manufacture, it may be assumed that their terms would amount to much the same. In which case the excess of extract beyond 6 per cent. would be the price to be paid by the planter for the manufacture of his sugar. In other words, the estate would have to pay for the cultivation of the soil, reaping the crop, and carting the canes to the works; that is, that its expenses would remain as they now are, those required for manufacture alone excepted, and in return for which 6 lbs. of sugar would be obtained for every 100 lbs. of canes produced.

I have already shown that every estate in the West Indies, with the means that it at present possesses, ought to produce from the canes cultivated upon it 12·6 per cent. of *dry* extract. Let us, however, admit that this is an exaggeration, and that the real product when dry would not exceed

8 per cent., which is equivalent to 6 lbs. of crystallised sugar and 3 lbs. of the molasses of commerce from every 100 lbs. of canes. In this case, were the foregoing arrangement entered into, the 3 lbs. of molasses would represent the price that the estate would have to pay for the manufacture of the 6 lbs. of sugar.

We will now suppose that an estate is so conducted that the amount of extract obtained shall observe the above ratio; that the work performed daily in the boiling-house is 2 tons of sugar and 2 puncheons of molasses of 10 cwt. each; that five labourers are employed at the mill and ten in the boiling-house, at a salary of 2*s.* each per diem. Let 20*s.* per diem additional be added for repair of works and other incidental expenses. The sum required to make this quantity of sugar and molasses would be 2*l.* 10*s.*, the difference between which and the value of the 20 cwt. of molasses will, it is evident, show the profit or loss that will accrue to the estate by the bargain. The molasses may, I think, be fairly estimated at 8*s.* the cwt., consequently the loss to the estate would be 5*l.* 10*s.*

It is presumed that the sugar produced at the factory would have a higher marketable value than that at present made in the boiling-house of the plantation. Such, no doubt, would be the case; but are we to suppose that the planter is the only person incapable of improvement?

Indeed one would be almost tempted to suppose that the advocates for separating the cultivation of

the cane from the manufacture of its juice into sugar entertain the idea that while all other branches of industry are daily advancing, the art of the planter alone is to remain stationary.

Unless, therefore, the proprietors of the factory are prepared to manufacture for an estate 2 tons of sugar and 1 ton of molasses for the sum of 2*l.* 10*s.*, I do not see how even the partial introduction of the measure is likely to prove beneficial.

3. *Would the scheme prove beneficial to its promoters?* — In calculating the probability of success likely to attend its adoption, that which has followed the establishment of sugar factories in India has been alluded to as an example. The comparison is, however, an unfortunate one, for the latter are in reality refineries similar in every respect to those in Europe, *kaur* and *ghour* (not cane-juice) being the materials operated upon. To make the analogy between the two schemes an accurate one, the central factory of the West Indies would be required to refine Muscovado sugar or to produce a crystallised extract from molasses or syrups.

The erection of a factory capable of making 1000 tons of sugar in five months would cost at least 20,000*l.*, which would entail an annual charge for interest, wear and tear of machinery, repairs, &c., of 15 per cent., and demanding from this cause alone 3*l.* per ton for all the sugar manufactured. The other charges for fuel, labour, clerks, management, &c., would cost at least 1500*l.* more. What,

it may be asked, would be the profit to the shareholders in such an undertaking?

I confess that in my humble opinion the promotion of this measure by a company got up in England would neither ameliorate the condition of the proprietors of sugar estates, nor would it prove a lucrative speculation to the parties concerned in it.

It is probable, however, that central factories might be erected with advantage in a few districts in the West Indies at the joint expense of the owners of the adjoining properties:—where the estates are small, where they are contiguous to each other, and where the works are inadequate for effective manufacture—I can conceive that the proprietors might advantageously throw their separate plantations together, and make of them one large estate, in the centre of which the factory might be established. A measure of this kind would at least have one advantage over the former, namely, that it would never be undertaken unless it were clearly ascertained to be the interest of the parties to do so.

A measure in some respects resembling this appears for a long while to have attracted notice in this country, and latterly it has put on a more definite form. There are in many of the West India colonies estates, which, from a variety of causes, are no longer cultivated, or which are fast ceasing to be so. The purchase of some of the more desirable portions of these lands, their cultivation in sugar canes, and the erection of ap-

propriate manufacturing establishments, have been seriously contemplated. Were it well carried out, such a scheme, I believe, would prove lucrative. It is one, however, that must be regarded rather in the light of a mercantile speculation than as a means for ameliorating the value of those plantations which are now in existence.

An idea has lately been entertained of importing the cane-juice in the form of an inspissated concrete, and of completing its manufacture into sugar in this country. The only objection to be taken against such a project is the present uncertain rate of duty to which the cane-juice prepared in this manner would be subjected. It is evident that if the planter were compelled to pay the same duty for a substance which would be of less intrinsic value than that which he now supplies, it would be his interest to continue the present system. But were the inspissated cane-juice admitted at such a reduction of the present sugar duties as would relieve him without diminishing the revenue, I believe that much benefit would result to all parties by the adoption of such a measure. The planter would be relieved from the difficulties that the deficiency of skilled labour causes, while he would, no doubt (if the concrete were properly prepared), obtain a larger amount of extract than he now does; the ship-owner would be benefited, as a greater tonnage would then be required; and the government, even if the reduction of duty were large, would receive as great, probably a greater revenue than at present. A hogshead, holding

200 imperial gallons, when filled will contain from 2800 to 2900 lbs. of syrup in the state in which it is when in the coolers, and of course a still greater quantity when the concentration has been carried beyond that point; but this amount, owing to leakage and other causes, is reduced to 1680 lbs. of sugar, and 600 lbs. of molasses, on arrival in this country; and on this amount only is the duty received, which is equal to 12*l.* If this duty were applied to the hogshead of concrete as first potted, it would amount to about 9*s.* 3*d.* per cwt. Let it, however, be raised to 9*s.* 6*d.* as a guarantee against any loss of revenue, and the advantages which would result to the planter would be very considerable.

Admitting that this measure were in full operation, the planter would still have much to do before he has completed the ameliorations expected from him. Without at present alluding to other matters, he would have to prepare the cane-juice in such a manner, that it shall arrive in Britain without having undergone any considerable change. The different stages of defecation, evaporation, and concentration would require to be performed in the most effective manner. The boon, although it must be admitted it would be a great one, would be far, indeed, from remedying *all* the losses at present sustained. To complete the advantages to be derived from the measure, other steps must at the same time be adopted.

The only rational mode of remedying an evil is,

in the first place, I repeat, to examine it closely and carefully, and having fully ascertained what is wrong, our attempts to rectify it will at least be pursued in a right direction. The evils which afflict West India property are both numerous and very serious. Many of them have been pointed out: they have been traced to their origin, and they have likewise been shown to be in a great measure easily conquered. Others which have not been stated for want of sufficient information respecting them doubtless exist also. Cane-juice in some of the colonies, for two months during the season of crop, has a density equal to 12° Beaumé, and consequently contains twenty-two per cent. of crystallisable sugar. May we not inquire why this is not of more frequent occurrence? This question involves others which are at present equally unknown, as the nature of soil, climate, &c. best suited for the advantageous production of the cane, the quality of manure demanded, and the system of cultivation that ought to be pursued. For we may presume that this plant, like many others, may, through the influence of cultivation, be caused to furnish one or other of its constituent principles in greater quantity than what it ordinarily yields. The Silesian beet-root, for instance, is found, from this cause alone, to contain at present a larger proportion of its saccharine constituents than it did when first employed for manufacturing purposes.

The sugar-cane has never been produced from seed in the West Indies, it is propagated by cut-

tings or germs: plants so raised, as is well known, become in time liable to deterioration and disease, and often entirely disappear.

There is, indeed, much reason for believing that this change has already commenced in the Bourbon and Otaheite cane. Ought we not to inquire, whether this disposition might not be checked, or whether a great improvement in the vigour of these plants might not be effected, by a change of cuttings between colony and colony, or even between plantations in the same colony?

Or would it not be useful to obtain occasionally a new stock from the countries which originally produced them?

These, and other questions of equal importance, cannot be answered, for as yet they have attracted no attention.

When we consider the vast interests involved in this branch of industry, it is truly wonderful that statistical information respecting our sugar plantations should be so scanty. Here and there, no doubt, an individual proprietor may be found who has expressed a desire for knowledge of this kind, but the means of acquiring it hitherto do not exist. It must, however, be acquired before we can expect to render those countries permanently prosperous.

Surely some measure may be devised for obtaining the fullest information on these subjects, and which may at the same time encourage and promote agricultural knowledge and manufacturing

skill among the persons employed in those pursuits. Societies composed of the most intelligent planters, and others interested in sugar plantations, ought to be formed in every colony for the purpose of discussing subjects of this kind. The societies of the different colonies should be associated by the exchange of each other's transactions. To render their object as practical as possible, a model farm and factory ought to be established in at least three different points in the West Indies, at which experiments may be performed, and their results fully ascertained. Moreover, that these societies may be connected as closely as possible with the progress of scientific discoveries and inventions in Europe, a central one ought to be formed in London, with which those of the colonies should be in frequent correspondence.

Agricultural societies, it is true, already exist in many of the colonies; but owing to the want of reciprocal communication, and to the lack of knowledge which their members possess of the subjects to be discussed, their efforts have hitherto produced little practical benefit, or, if any has been obtained, it is confined to the place where it originated.

Had such a measure as the above been already in operation, we should have heard less of the pecuniary losses annually entailed by the importation of costly machinery, which in so many instances has been abandoned and thrown aside, either from its unsuitableness to the purposes intended, or from the ignorance of its management

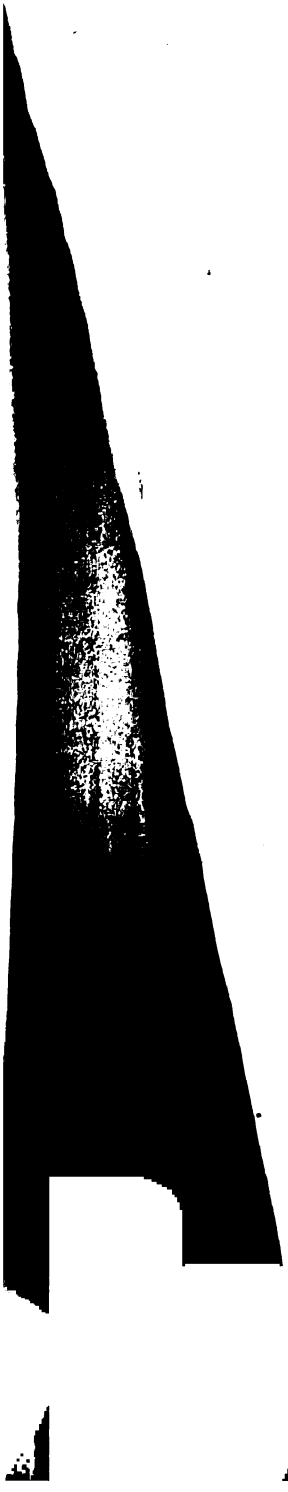
by those for whose use it was purchased. There would also have been more unanimity respecting the advantages or disadvantages attending the employment of various kinds of manures which have at different times been recommended or abused, but the introduction of which, it is certain, has not unfrequently been attended with great pecuniary loss.

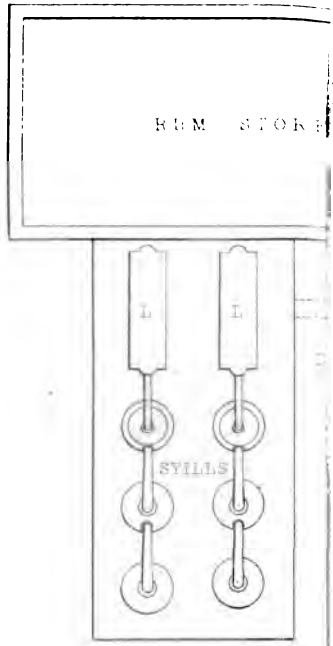
If these suggestions are worthy of adoption, any measure based upon them (if we are anxious for its successful result) should be carried out fully, energetically, and with a unanimous conviction of its necessity.

It is probable that many persons owning property in the West Indies may have formed opinions widely different from those which I have expressed. They may, perhaps, tell us that all the efforts which they may make for augmenting the production of their estates, or for diminishing its cost, are measures which may likewise be adopted by their slave-holding opponents; and that consequently the result, although it would be a beneficial one to the consumer, would confer no advantage on themselves.

They may say that while the disproportion between the amount of protection given to their products, and the difference of cost between slave and free labour, exist, all their attempts at ameliorating their position would prove at best to be nugatory. This argument supposes that the slave-owning sugar-grower possesses advantages over

the British planter, either in the cheapness of his labour, or in other respects, which, though not clearly made out, nevertheless may be supposed to exist. In answer to the first assumption, namely, that the labour of slaves is cheaper than that of freemen, it may be said that both reason and experience have proved its falsity. Labour is the means to obtain a purpose, and its expense must be measured by the value received from it, and not merely by the daily disbursements made in the shape of wages. Were a system of husbandry continued in the British colonies similar to the one pursued during slavery, I admit that slave labour would prove to be the cheaper of the two; but were a proper and economical method, similar to what we see in Great Britain and many other countries, substituted for the barbarous employment of the hand-hoe, the reverse, I apprehend, would be found to be the case. Slavery is a bar to general improvement, and it is principally to habits and modes of managing his property, acquired during its existence, that the British planter may attribute his present backwardness. The employment of the plough and horse-hoe for instance, will never be general in a country where slave labour is trusted to for the cultivation of the cane. Wherever slavery exists, its numerical force must be adequate to all the calls that may be made upon it at any one time. Thus if 300 labourers are required during crop, this number must be retained throughout the whole year; and if they




RUM STORE
L
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SYILLS

REFERENCES TO PLATES.

Plate I.

PRESENTS the ground plan and sections of buildings
d machinery for the manufacture of 500 tons of sugar
five months. To render the explanation clear and
ntelligible, it may be as well to trace the process of
anufacture from the cane mill to the curing-house, by
which means the uses of the various utensils will be more
apparent.

When the cane is crushed at the mill, A, the liquor is raised (by the juice pumps attached to the mill) and carried overhead by spouts, to the clarifiers, C.

The steam engine adjoins the cane mill, and is supplied with steam by the boilers, B; these also supply the clarifiers and all utensils connected with the plant which require steam. In connection with each set of clarifiers is a double set of bag filters, D, through which the liquor is rapidly passed into cistern No. 1., and which is seen partially under the clarifier platform. From the cistern No. 1. the liquor is then passed into the flat-bottomed evaporators, E, (by means of the monte-jus, F,) where it is concentrated to the required density.

The evaporators are of the form and construction already described. They may be heated by steam or open fire. When the latter mode of heating is employed, the dotted lines and arrows shown in No. 2. explain the direction of the flues.

The liquor being concentrated in them to the given density, is then returned to the monte-jus, F, and by it forced up to the cistern No. 2., above the six charcoal filters, G, and having forced its way through them, it passes into cistern No. 3., from which it is run, as occasion may require, into the patent pans, H H.

The charcoal cisterns and filters are here shown, not as essentials to a complete plant, but with the view of showing the arrangement of a plant where they may be considered necessary, and where such is not the case, the monte-jus, F, will simply discharge the concentrated liquor into the cistern No. 3.

The stills are shown outside of the buildings: they are fired from the same stoke hole as the patent pans. The third still is mounted with Shears's rectifier, the worm passing through a reservoir of water, L, and terminating as usual in the rum store. Alongside the patent pans a small crank-over-head engine is placed, for the purpose of driving the gearing and cylinders of the pans.

Plate II.

In this plate the letters and references are the same as in Plate I., the plant being adapted for making double the quantity of sugar in the same time, viz. 1000 tons in five months. The only difference of importance in the arrangement is, that a seven-foot vacuum pan, V, is introduced instead of the patent pans of Plate I. The vapour from it passes along to the condenser, M, which consists of four ranges of copper pipes, having from fifteen to twenty pipes in each range, and water dripping over them.

A small beam engine is shown alongside the vacuum pan, for working the air pump attached to the condenser.

A second monte-jus is also introduced in this plant. The one to throw the clarified liquor from the bag filters to the evaporating vessels, the other to land the syrup as it leaves the latter vessels into the charcoal cistern.

It may be observed, that the evaporating vessels are shown with a division in each, so that at the time of skipping a necessary quantity of fresh liquor may be retained in the first compartment to protect the pan from the action of the fire. The liquor is admitted into the second compartment by means of a valve. They are also shown in section No. 2., Plate I., as being made with shelving sides, which permit of an increased quantity of liquor being admitted previous to each skipping.

General Remarks.

The granulating or patent pans in Plate I. being fitted with a cock or valve in the bottom, the sugar may be struck into caissons, and transferred on a tramway passing under the clarifier platform into the curing-house.

The sugar from the vacuum pan in Plate II. will be struck through a spout in the wall, and pass at once into the crystallising vessel placed in the curing-house to receive it.

The doorways are shown in various parts of the buildings, but these may be modified to suit local circumstances. In both of these designs all the stoke holes are outside of the buildings, and one chimney stack serves for all the fires. In Plate II. the passage of the flues from the boilers, evaporators, and stills, are dotted in to the chimney.

The boilers will be in both plants worked high pressure, and if a low-pressure engine is preferred for the cane-mill, it must be provided with an expansion valve to cut

off at $\frac{1}{3}$, $\frac{1}{4}$, or whatever part of the stroke may be required according to pressure.

If a high-pressure engine is used, the exhausted steam, after having heated the water for the boilers, may be made to circulate in pipes round the interior of the curing-house, so as to improve the granulation and drainage of the sugar, by raising and preserving a uniformity of temperature in the building.

The plant in Plate I. is laid down upon a scale of one eighth of an inch to a foot, and the large plant in Plate II. is laid down upon a scale of $\frac{5}{32}$ of an inch to a foot.

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